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Evaluation of the HARDMAN Comparability Methodology for Manpower, Personnel, and Training

W. Zimmerman
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February 29, 1984

Prepared for
U.S. Army Research Institute for the Behavioral and Social Sciences
Through an Agreement with
National Aeronautics and Space Administration
by
Jet Propulsion Laboratory
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ABSTRACT

The methodology evaluation and recommendations presented in this document are part of an overall effort initiated by the Army to improve its Hardware versus Manpower (HARDMAN) methodology for projecting manpower, personnel, and training (MPT) to support new acquisitions. Several different validity tests were employed to evaluate the methodology. These tests included (1) a general examination of the basic reasonableness of the technique; (2) a reliability measure of how well other trained individuals, given the same data inputs, can derive the same answers as an already-completed test case; (3) a qualitative accuracy check based on talking to individuals who have already applied the same, or similar, methodology; and (4) a simple measure of how accurately the methodology must predict the real world. The net outcome of the study revealed that the methodology conformed fairly well with both the Army's MPT user needs and other accepted manpower modeling techniques. Additionally, audits of three completed HARDMAN applications revealed only a small number of potential problem areas compared to the total number of issues investigated. The reliability study results conformed well with the problem areas uncovered through the audits. The major problems discovered basically revolved around (1) a need to tighten up select judgmental portions of the methodology, and (2) a requirement to improve those aspects of the technique used for making MPT support and budget decisions. The results of the accuracy studies suggested, respectively, that although no firm accuracy judgment could be made at this time, the manpower life-cycle cost component was only marginally sensitive to changes in other related cost variables. Therefore, even with some minor problems, the methodology seemed to be sound and to have good near-term utility to the Army. Recommendations were provided to firm up the problem areas revealed through the evaluation.

FOREWORD

This document provides the results of the first phase of an evaluation effort designed to examine and improve the Army's HARDMAN manpower projection methodology. The work was performed by JPL and was sponsored by the Army Research Institute for the Behavioral and Social Sciences (ARI) through a reimbursable agreement (ARI Nos. 13ARI19 Change 1 and 13ARI83-35, respectively dated February 15 and March 9, 1983) with the National Aeronautics and Space Administration (Task RD-182, Amendment 256). Dr. John Whittenburg, Team Leader for the Systems Manning Technical Area, is the task officer.

In a literal sense, this document is the product of a team effort. Wayne Zimmerman, the Task Manager and prime author, was assisted by several colleagues. Valerie Gray was responsible for the user requirements portion of the study and assisted in performing the reliability study. Leigh Rosenberg organized and conducted the reliability study. As an adjunct to the reliability study, Robert Butler, of the Assessment Group consulting firm, performed the event-series validity evaluation. Mark Franklin and Steven Parks participated and provided assistance, respectively, in the SINCGARS replication and technical audit efforts, which were part of the validity studies. Shirley Stroup was responsible for typing the document.

ACKNOWLEDGMENT

We would like to acknowledge the cooperation and assistance provided by the Soldier Support Centers (SSC) at Fort Benjamin Harrison, Indiana, and Alexandria, Virginia; the Army Research Institute (ARI); and the SINCGARS Program Office, which participated in the study. A special acknowledgment is extended to the Dynamics Research Corporation (DRC) HARDMAN team for their time, cooperation, and participation in the evaluation.

GLOSSARY

AOSP	Army Occupational Survey Program
AR 611-201	Army Regulation for Enlisted Career MOS Management Fields
AR 570-2	Army Regulation for Manpower Authorization Criteria
ARI	Army Research Institute for the Behavioral and Social Sciences
ARTEP	Army Training Evaluation Program
ASARC	Army Systems Acquisition Review Council
BOIP	Basis-of-Issue Plan
CDB	Consolidated Data Base
CFP	Concept Formulation Package
COEA	Cost and Operational Effectiveness analysis
CRT	Cathode-Ray Tube
DA	Department of Army
DCSCD	Deputy Chief of Staff Combat Development
DCSLOG	Deputy Chief-of-Staff Logistics
DCSPER	Deputy Chief-of-Staff Personnel
DCST	Deputy Chief-of-Staff Training
DID	Data-Item Description
DOD	Department of Defense
HARDMAN	Hardware vs. Manpower
HCM	HARDMAN Comparability Methodology
HTRRDM	HARDMAN Training Resource Requirements Determination Methodology
HLCCM	HARDMAN Life-Cycle Cost Methodology
HIS	HARDMAN Information System
HQDA	Headquarters, Department of the Army
ICTP	Individual and Collective Training Plans
ILS	Integrated Logistic Support
ILSP	Integrated Logistic Support Plan
ISS	Integrated System Support
JPL	Jet Propulsion Laboratory
LCC	Life-Cycle Cost
LEA	Logistics Evaluation Agency
LOA	Letter of Agreement
LOGCEN	Logistic Support Center

LSA	Logistic Support Analysis
LSAR	Logistic Support Analysis Record
MACRIT	Manpower Authorization Criteria
MANPERS	Manpower and Personnel Requirements Determination Methodologies
MMH	Maintenance Man Hours
MOS	Military Occupational Specialty(ies)
MPT	Manpower Personnel and Training
O and O	Operational and Organization
OICTP	Outline Individual and Collective Training Plan
POI	Program of Instruction
PQA	Preliminary Quantitative Assessment
QQPRI	Quantitative and Qualitative Personnel Requirement Information
RAM	Reliability, Availability, Maintainability
RFP	Request for Proposal
SDD	Soldier Development Directorate
SQT	Skills Qualification Test
SSC	Soldier Support Center
SSC-NCR	Soldier Support Center-National Capital Region
SSG	Special Study Group
TAD	Target Audience Description
RG	Training guide
TOE	Table of Organization and Equipment
TQQPRI	Tentative Quantitative and Qualitative Personnel Requirements Information
TRADOC	Training and Doctrine Command
TSM	TRADOC Systems Manager

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SECTION I

INTRODUCTION AND SUMMARY

A. OBJECTIVES

The Jet Propulsion Laboratory (JPL), sponsored by the Army Research Institute (ARI), was asked to provide the Army with an objective, independent assessment of the validity and reliability of the HARDMAN (Hardware vs. Manpower) Comparability Methodology (HCM) for projecting manpower, personnel, and training. JPL was also asked to make recommendations for needed improvements in the methodology that would ultimately help the Army implement an accurate manpower, personnel, and training (MPT) system that could be applied early in the acquisition process of new systems.

The following paragraphs discuss the major assumptions and constraints that established the framework of the study, the background behind the Army manpower and training issue, the evaluation approach and summary of results, and the overall structure of the document.

B. BACKGROUND

Having stated the overall objectives of the study, it is appropriate at this time to provide a brief summary of the background of the task.

Over the past several years, the Army has recognized a critical manpower situation revolving around the widening gap between increasing weapon complexity and declining manpower availability. The problem of declining manpower availability has been further aggravated by the apparent decay of entrant skill levels. An effort was initiated by ARI in 1980, as part of an Army-wide interest to improve the manpower problem, to determine whether a Navy methodology called HARDMAN (HARDware vs. MANpower) could be applied to Army systems. The Army was interested in determining whether an existing manpower, personnel, and training projection technique could be modified to provide early, accurate inputs to the acquisition process. The Army chose to examine the HCM (one of several methodologies developed under the auspices of the Navy HARDMAN Office) because it was an integrated MPT technique and had already been used in several Navy acquisition programs. The other Navy methodologies appeared to be too narrow in scope or required input data not available under the Army's existing data collection systems. Although these systems have not been ruled out for Army use, it seemed that for the near term, the greatest payoff rested on the HCM. The HCM contains the following six major steps:

(1) Establish a consolidated data base composed of functional descriptions of the proposed and similar predecessor systems; and associated inputs such as hardware reliability, personnel information, costs, and training data. This information is used to

support succeeding steps in the analysis. This step is essential because the Army does not usually organize and store data in effective structure to conduct human resource analysis.

(2) Determine the manpower requirements and skills necessary to operate and maintain the system.

(3) Determine training requirements likely to be imposed by the proposed system.

(4) Determine personnel requirements (i.e., personnel flows that will be necessary to support the manpower requirements).

(5) Conduct an impact analysis to establish likely manpower and training shortages and identify parts of the system that represent high-cost drivers.

(6) Perform a tradeoff analysis to alter features of the system (e.g., reliability or required skill levels) to reduce or eliminate unreasonable demands.

Each of these steps involves several judgments pertaining to the selection of comparable predecessor systems, the identification and assembly of associated data on the predecessor systems, expected performance of the proposed system as compared to predecessor systems, and required skills. Additionally, gaps in the supporting data often exist at the conceptual design stage. At these junctions, expert judgment is exercised to merge the various pieces of information into a comprehensive, consistent picture to be used to generate the personnel projections. The Army's concern is that these judgment areas could act as major error sources in the manpower projection. Consequently, JPL was asked to perform an objective evaluation of the methodology to identify both strengths and weaknesses of the technique and make recommendations, as appropriate.

C. ASSUMPTIONS AND CONSTRAINTS

One of the methodology validity tests involved a comparison of the user needs against the proposed outcomes of the projection scheme. To establish the user requirements, a detailed interview process was designed to use the bank of experience already existing in the Army. The major assumption involved with the user requirements effort centered on the user contacts. Because the user contacts in the various Army commands were established via the sponsor and recommendations from the users themselves, it was assumed that the suggested sources were sufficiently experienced and knowledgeable in the MPT arena so that their answers were representative of the respective commands in general. Even though the sample size was small, the consistency of the responses suggested that the answers were a good representation of the Army as a whole.

Several limitations were imposed on the study. The size of the sample user population was limited primarily by the available time to complete the evaluation. Some of the users contacted were more informed or aware than others about MPT processes or projection models such as the HCM. Therefore, it was understood that some of their responses could reflect an already established preference, depending on their knowledge of the various elements present in the HCM or other MPT models. To circumvent this bias, the questionnaire and interview technique employed in this evaluation focused on getting the user to provide requirements for a "generic" MPT projection system for the Army.

It should be noted that the user requirements determined by this study reflect the needs of a present or near-future MPT system. Any changes to this environment could result in additional or different requirements (e.g., implementation of Integrated System Support (ISS)). Therefore, it is important that the Army consider periodic reevaluation of its MPT requirements to ensure that any in-place MPT system remains responsive to the needs of the various MPT players.

Although it was originally planned to do a thorough validity and reliability evaluation of the methodology, internal time and budget limitations resulted in the sponsor opting to defer (1) the accuracy check on the MPT methodology, (2) the life-cycle cost (LCC) and methodology sensitivity analysis, and (3) the quantitative accuracy check on the methodology input data (e.g., reliability and maintainability data). Finally, other duty commitments required that the internal validity experiment be simplified so that the Army participants could finish the replication within a maximum three-week time frame.

D. SUMMARY OF EVALUATION APPROACH AND RESULTS OF ANALYSIS

The preceding discussion outlined the various steps and judgments necessary to exercise the HCM. Because of the breadth and complexity of MPT issues covered by the technique, a multifaceted evaluation was structured to examine potential validity aspects. The validity aspects, evaluation approach, and study results are summarized in the following paragraphs.

1. Evaluation Approach

As stated earlier in this section, time and budget constraints limited the original scope of the study. Validity measures related to testing model accuracy were deferred to the next study phase. However, within the imposed constraints several other validity tests were conducted. Face validity, a measure of whether the model appears logical and reasonable, was the first aspect investigated. Although not a rigorous credibility test, a face-validity study does afford some insights into the general utility of the model, potential error sources, data availability problems, logic foundation, and possible ambiguities in logic structure or results. The approach for performing the face-validity examination was fourfold. First, a user requirements study was performed to establish the Army's needs within the MPT

community. A total of nine distinct user groups (thirteen individuals) were interviewed in person to establish user MPT needs in areas, ranging from the basic design of the MPT projection system to the kinds of information desired from the system outputs. A basic utility test was then performed by comparing each user requirement against the same respective element in the HCM. Second, existing DOD and Army directives were examined to see whether there were any established, accepted MPT techniques presently in use that could be used to confirm the general logic structure and data foundation. Third, a larger literature search was conducted, encompassing other government agencies and the private sector. Again, the object was to develop a firm basis for evaluating the logic and data support structures of the HCM, as well as examining potential sources for error. Last, detailed audits were conducted on three applications of the methodology. Independent analysts attempted to replicate major empirical and judgmental steps in each application with the intent of examining overall logic, potential sources of errors, data manipulation or availability problems, and ambiguities in how the projections were derived and interpreted.

Another test, internal reliability, was employed to get an understanding of the ability of others to successfully apply the technique and obtain consistent answers. An internal validity test is essentially a measure of the variance in model outputs when a group of independent analysts replicate an already completed application given the same inputs. Ultimately, the objective is to establish the clarity and succinctness of the model, as well as the ability to have any reasonably trained individual perform the process reliably. An actual Army system was selected for the internal validity test. A group of seven individuals (four civilians and three Army officers) were initially trained in the execution of the HCM and then provided with data packages that allowed them to conduct a "limited" manpower and personnel assessment on the proposed system (i.e., because of other duty commitments and resultant time restrictions, only four major components of the system were studied).

It was decided that an attempt should be made to examine model accuracy from at least a qualitative standpoint. To this end, several individuals in both the Air Force and Navy, who had experience with applications of the same (or similar) MPT model, were contacted for information pertaining to any tests or actual comparative field data that might indicate the relative accuracy of the methodology.

Finally, the last validity aspect examined was an event-series test. Event-series validity is basically a measure of how accurately a simulation must reproduce a real-world event. A top-level, life-cycle, cost-sensitivity analysis, keying on the manpower variable, was employed as the tool to achieve this measure. The required accuracy of the manpower variable was determined by performing iterations of the life-cycle cost projection (using an example acquisition) until all other dependent variables, manning, and total life-cycle cost fell within prescribed error bounds. This measure was particularly important for obtaining a further understanding of the model usefulness as a decision making tool.

Throughout all of these validity exercises several strengths and parallel problem areas surfaced. The complete results of the evaluation are summarized in the following discussion.

2. Summary of Results

Table 1-1 provides an overall summary of the study results. Each of the above evaluation areas is discussed briefly in the following paragraphs.

Table 1-1. Net Results of HARDMAN Evaluation

Evaluation Areas	Net Results
User Requirements	Technique complied with majority of mandatory user requirements
Operational Analysis	
Comparison with other MPT methods	Methodology conformed with other known, accepted MPT modeling schemes, and data foundations
Audits	Methodology demonstrated sound logic and reasonable results for 85% of test issues examined (remaining issues considered reparable in near term)
Reliability Analysis	
Internal reliability	Test group correctly replicated half of selected test points (two of the four remaining test points found to be repeatable after clarification)
Qualitative Accuracy Check	Two of nine individuals having experience with HARDMAN applications indicated a rough accuracy of 80-90% with actual manning requirements; remaining individuals had insufficient experience to comment
Event Series Validity	Manpower variable found to be least sensitive of all life-cycle cost variables, demonstrating good utility of existing methodology even without suggested near-term improvements

a. User Requirements Analysis. The user requirements analysis generated a total of twenty-two mandatory MPT system requirements. Thirteen of the mandatory requirements applied to system outputs, and the remaining nine requirements were related to system design. An additional four requirements were given lower priority by the users and were therefore listed as "desirable." The major thrust of the user needs revolved around the key design drivers of affordability, supportability, and sustainability. By comparison, it was found that the HCM complied with seventeen of the twenty-two mandatory requirements. The areas of noncompliance were as follows:

(1) Not indicating the accuracy of the MPT projection system to aid budget control and program-level decisions.

(2) Not including demographic data such as age, sex, size, etc., as part of the man-machine matching and support process.

(3) Not considering the demands of other acquisitions on the available manpower pool (i.e., the HCM still focuses primarily on the individual equipment system).

(4) Not performing a complete life-cycle cost tradeoff analysis (i.e., the HCM focuses only on MPT costs).

(5) Not indicating weaknesses in the MPT analysis along with respective resolution actions.

Overall, it seems that the HCM is reasonably responsive to the Army's needs.

b. Operational Analysis. The literature search and audit aspects of the face validity study were jointly conducted under the operational analysis portion of the evaluation. This portion of the overall study was broadly termed "operational analysis" because the ensuing investigation required a rigorous exercising of the HCM. The review and comparison of related DOD and Army directives provided three major findings: (1) DOD system acquisition guidelines stated a requirement to consider MPT in the design process but did not appear to afford a means of projecting MPT requirements; (2) the Army Manpower Authorization, Criteria (MACRIT) guide did provide a simple manpower projection algorithm; and (3) the HCM appeared to be designed around the MACRIT manpower algorithm, with its outputs generally organized to conform with broader DOD acquisition directives. These insights, although serving as good initial data points, only addressed a fraction of the total methodology. The follow-up government and private-sector literature searches were far more intensive. Nineteen other MPT models and papers, encompassing all aspects of the HCM, were studied. Generally, it was discovered that the other modeling approaches were reasonably equivalent in their assumptions, algorithms, and data inputs. In one area, the personnel pipeline projection, the HCM approach was found to be stronger because it

employed a modeling technique that reduced the need for difficult-to-obtain data such as present and future manpower availabilities. On the negative side, it seemed that there were four distinct areas where potential inaccuracies could be interjected: (1) The use of the MACRIT manpower algorithm could result in early or late life-cycle manpower projection errors unless system deployment and phase-out rates are considered; (2) non-consideration of major socio-economic factors such as the draft, economy, change in federal government administrations, or massive military reorganizations could influence the attrition and retention characteristics of personnel career paths; (3) the non-use of some type of long-term manpower availability projection to indicate shortages at the time of system deployment could result in sizeable personnel errors; and (4) the lack of a complete life-cycle cost model could prevent the full range of potential cost and system design tradeoffs from being provided to the decision makers.

The last aspect of the face-validity analysis, the audits, revealed that the model successfully passed eighty-five percent of the test issues examined. The remaining potential problem areas discovered were (1) the lack of a structured process of selecting, adjusting, and manipulating the source data could sizeably affect the accuracy and credibility of the projections; (2) the use of a single reference system (composed of similar predecessor components) to model several widely varying proposed designs could also affect the accuracy and credibility of the results; (3) the absence of an adjustment to the complete predecessor historical data to consider the design improvements of the proposed system means that it would not be feasible to make a valid comparison between real world performance and the often overly-optimistic projection of the contractor; (4) the lack of a structured process for approximating the value of peculiar design changes or induced human error as related to component failure rates presents a means of interjecting computational mistakes as well as reducing both the audit and usability capacities of the method; (5) the absence of indicators for data quality and projection accuracy could affect the credibility and usefulness of the results; and (6) the complexity of the technique requires the use of a well-seasoned, multi-disciplinary team which, in turn, could impact the ability of others to apply the method.

c. Reliability Analysis. The last parts of evaluation, the internal and event-series validity tests and qualitative accuracy check, were performed under the reliabiity analysis. This was done because all of these validity aspects related to both the internal and external reliability of the process. The results of the internal validity check were closely aligned with the audit findings. As a whole, the test group discovered that, given the same inputs, it could not replicate the original SINCGARS results. Although all of the study group seemed to understand roughly half of the early steps in the process reasonably well, they had problems with (1) developing a reference system that jointly met the functional requirements and was representative of the two widely varying contractor designs; (2) not understanding the thought process for determining impacts of design differences, and how and when to perturb historical predecessor data to model components of the proposed system; and (3) not comprehending the exact process of matching or selecting skills. After items (1) and (3) were clarified, the study group had a fairly

good grasp of the majority of the early steps in the process. The test subjects uniformly agreed that none of them singularly had enough training or educational background to exercise the complete methodology with any confidence.

The major finding in the event-series validity study was that the MPT projections could easily vary by plus or minus fifteen percent without causing major problems at the upper DOD budget and cost control management levels. Component usage rate was found to have the greatest influence on causing unacceptable errors in manpower projections. Although it was jointly discovered that there is still not sufficient historical experience to make a firm qualitative accuracy judgment on the process, the low sensitivity finding on the manpower variable was a promising indicator of the utility of the model even with its minor drawbacks.

d. Conclusions and Recommendations. In conclusion, it was felt that, overall, the HCM appeared to be reasonably sound. The flaws discovered did not appear to be irreparable. The major near-term recommendations suggested to tighten up the problem areas were as follows: (1) Establish subjective criteria for rating the quality of various data sources; (2) provide an indication of the credibility of the projections; (3) establish a top-level method for comparing the technology of the reference and proposed systems on an equal basis; (4) establish solid guidelines and information sources for building reference systems and consider the use of two reference systems to model two widely varying contractor-proposed designs; (5) firm up guidelines for the functional requirements level of indenture; (6) provide a better structure for MOS and skill selection; (7) periodically update manpower projections (every two to four years) over a system's life cycle to offset possible end-point errors; (8) provide a more structured tradeoff process; and (9) standardize the assessment of study weaknesses and resolution actions.

The intermediate term (two years from the present) priorities were (1) project manpower availability out to the actual system deployment date; (2) incorporate a more complete life cycle cost tradeoff analysis; (3) firm up ranges for perturbation values, induced failures, and indirect productivity factors.

Far-term recommendations (for the three- to five-year time frame following the present) included (1) consideration of other emerging system manpower demands; (2) development of a quantitative means to differentiate between critical and non-critical tasks; (3) expansion of the demographic data base; and (4) consideration of major socioeconomic fluctuations. Potential solutions for all of the preceding recommendations were also provided.

In addition to these recommendations, it was also suggested that, based on the audit and reliability findings, future HARDMAN training programs solicit a multidisciplinary team of individuals with backgrounds in the military, engineering, information systems and data management, and personnel. Further, combinations of two of more of these disciplines in each individual as part of the overall multidisciplinary team seem to form the best foundation for accurately exercising the methodology.

E. STRUCTURE OF DOCUMENT

This document is structured so that a brief history of both the HARDMAN effort and Army involvement in HARDMAN is provided first in Section II as a basis for the study. Section III discusses the overall design of the analysis and broadly explains the purpose and content of the various validity studies. Sections IV through VI provide the detailed results of the methodology evaluation in the major areas of user requirements, face validity (operational analysis), and reliability (internal and event-series validity). Finally, Section VII discusses the implications of the results and provides the overall assessment of the technique with recommendations.

SECTION II

HARDMAN BACKGROUND

A. OVERVIEW

The previous section provided a brief summary of the evaluation approach and results. As stated earlier in Section I, the Army has been concerned about the widening gap between growing technology and decreasing availability of needed skills. Manpower guidelines already exist through DOD documents such as the 5000 series and Military Standard (MIL-STD) 1388. These documents, which establish acquisition and support procedures for new systems, address the requirement to have a proper man-machine balance but do not specify techniques to accomplish the balance. Given the ever-widening technology and skills gap, the Army has been pressed to develop clear, accurate manpower projection techniques to fill the void in existing DOD acquisition guidelines. The following paragraphs provide a brief summary of the history and progression of events leading up to the Army's decision to develop an appropriate MPT projection system.

B. HARDMAN HISTORY

The weapon system acquisition process has evolved over a long period of time. The overall system acquisition strategy suggests that the number of competing alternatives should be narrowed by eliminating those concepts no longer considered viable as a function of four major measures (1,2): (1) the ability of a design to meet the proposed mission; (2) the compatibility of the design with the anticipated threat; (3) a comparison of each concept with operational requirements; and (4) a comparison of each design's threshold values (i.e., cost, performance, readiness, and supportability impacts). These measures are employed throughout the system development process. The development process consists of four phases containing three major milestones or acquisition decision points (2):

(1) Phase I (Milestone I) - Concept development.

(2) Phase II (Milestone II) - Concept demonstration and validation.

(3) Phase III (Milestone III) - System development.

(4) Phase IV - System production and deployment.

At the end of each phase or milestone, a go/no-go decision is made by the Army System Acquisition Review Council (ASARC) and Defense System Acquisition Review Council (DSARC) as to whether to proceed to the next milestone (1,2). A key consideration in all of the preceding measures and subsequent decision points is the integration of manpower, personnel, and training (MPT)

into new designs. Recent studies (3, 4) by some of the services (i.e., Air Force and Navy) indicate that operations and support costs can consume from 40 to 50% of the total life-cycle cost of a weapon system. Additionally, the manpower component of the support portion of life-cycle cost can consume as much as 60%. These studies underline the growing importance of MPT.

Although the Air Force was the first service to develop a major thrust to resolve the MPT dilemma, the actual formalization of the HARDMAN concept, as presently defined, started with the creation of Navy's HARDMAN Development Office in 1977 (5). The Navy's HARDMAN effort was initiated partially because of studies similar to References 3 and 4 and to the fact that present DOD directives do not adequately define methods for projecting MPT requirements for new acquisitions. The first Navy HARDMAN study, initiated in 1975, was funded by the Chief of Naval Operations (CNO) Studies and Analysis Program. This study established that (1) systems were being designed without adequate attention given to MPT costs and (2) logistics support planning (and in particular MPT) for new acquisitions was inadequate. The CNO study outlined the following solutions:

(1) Develop analytical tools and methods for MPT to influence the weapon system acquisition process.

(2) Develop an MPT information system.

(3) Revise existing directives governing the acquisition process to be more sensitive to MPT.

As a result of the CNO study and some aggressive management, the Navy established the HARDMAN office and set about developing a modeling system composed of four linked components consistent with the aforementioned CNO guidelines and tailored to the various design phases.

The linked modeling system, which is the present HARDMAN design, basically consisted of the following:

(1) A manpower projection model.

(2) A training resource assessment.

(3) A life-cycle cost analysis.

(4) A HARDMAN information system.

The manpower projection link of the system (HCM) was designed by Dynamics Research Corporation (DRC) and was developed around the concept of using information from similar predecessor technology as a basis for manpower projections (6). Drawing on an extensive historical data base as well as the new design inputs, the manpower for the proposed system is estimated by altering the historical data as a function of the peculiar design improvements and fitting these results into a simple manpower equation consisting principally of total workload manhours and total systems to be procured. The HCM proceeds to establish required skills, training, MP costs, and potential personnel shortages through the remaining steps in the methodology. MPT estimates are then refined as the input data matures through subsequent design stages.

The PACER Corporation developed the training resource link (HTRRDM), designed to provide a checklist and straightforward algorithms for defining elements such as training sites, instructors, instructional devices, course material, and training costs (7).

The life-cycle cost link of the HARDMAN system (HLCCM) was developed by the Assessment Group firm and designed in two levels of detail to be commensurate with the different stages of design development. Drawing on standard life-cycle cost algorithms, a skill-cost model, and designer inputs, the technique provides both the total-system, life-cycle cost and the ability to quickly perform life-cycle cost tradeoffs between various logistic elements (8).

The last system link, the HARDMAN Information System (HIS), was designed by Ackman Associates. Although not completed, the HIS is structured to be the repository for all predecessor system MPT and life-cycle cost data as well as data for new potential acquisitions.

The Navy effort has considerable value for several reasons. Most important is the clear demonstration of the necessity to bond MPT securely with the acquisition community. Another clear value of the Navy's effort revolves around the many manpower models developed by DOD and the various services over the past several years. These models generally have only addressed select aspects of the MPT problem such as manpower flows in and out of various skill areas or total manpower requirements. The Navy's thrust has been to develop a total MPT system, which extends beyond these smaller studies. Additionally, the Navy's program has produced a large bank of experience and MPT tools.

C. ARMY INVOLVEMENT IN HARDMAN

Like the Navy, the Army has been observing similar problems with the mismatch between advancing technology and decreasing availability of skills. In 1980, the Army Research Institute (ARI) initiated an effort, in support of the Army-wide interest in the system manning problem, to establish whether the Navy HARDMAN effort could be tailored for use on new Army acquisitions. Recognizing that approximately seventy five percent of the system acquisition cost is committed by Phase II of the development cycle, the Army was also interested in determining whether the technique could provide early, reasonably accurate MPT estimates. As indicated in the preceding section, there was considerable overlap between the comparability, training, and costing links. Because it appeared that the HCM was the most encompassing and mature of the MPT models, ARI decided to perform some test applications of this technique as well as a validation of the methodology. To date, the Army has funded four test applications: Corps Support Weapon System (CSWS), Division Support Weapon System (DSWS), Remotely Piloted Vehicle (RPV), and Single Channel Ground Airborne Radio System (SINCGARS). The study performed in this document represents the first segment of the Army's validation effort and draws on the results of three of the test applications. The HCM presently represents a possible near-term solution to the Army's MPT dilemma.

D. DESCRIPTION AND INTENDED USE OF THE ARMY HARDMAN SYSTEM

The Army HARDMAN system is presently emphasizing only the HCM. The technique consists of six major steps as shown in Figure 2-1 (6). Step 1, Establish Consolidated Data Base, includes the development of functional descriptions of the alternate systems and the collection of the input data (hardware, personnel, training, and cost) needed to support the succeeding analyses. Step 2, Determine Manpower Requirements, refers to the process of identifying the number and skills of soldiers necessary to operate and maintain the system. Step 3, Determine Training Requirements, is done in parallel with Step 4 and requires the specification of the numbers and types of instructors, courses, media, and training devices, etc., which are necessary to accommodate the new equipment. Step 4, Determine Personnel Requirements, addresses the activity of identifying the peculiar occupational speciality requirements. Step 5, Conduct Impact Analysis, focuses on the activity of comparing assessed demands (from Steps 2-4) and available supplies and notes unreasonable resource demands in terms of both manpower and training costs and personnel. Step 6, Tradeoff Analysis, refers to the activity of altering features of the system and repeating Steps 1 through 5 to reduce or eliminate unreasonable demands.

Within each step there are several judgments required that are basically satisfied by using experience from the new system designers or a group of outside experts (6). For example, in Step 1, the evaluator(s) is required to interpret documents and use personal judgment in establishing the functional requirements for the new system and in selecting similar predecessor components that most closely meet these requirements. In Step 2, generic kinds of tasks must be defined and assigned to the various echelons of maintenance (i.e., organizational level in the field and intermediate level removed from the field). Step 2 also requires the evaluator(s) to make educated guesses as to the split between inherent versus induced component failures, design differences, selection and assignment of skills for the various tasks, and probable system and component usage rates. In Step 3, the analyzer must decide which kinds of predecessor training resources are applicable to the proposed system and, where no training scenario exists, generate new training resource requirements. Steps 4 and 5 involve judgments about the movement and availability of people both within various skills and the Army as a whole and also require the development of options to offset high demands. Step 6 does not require any major judgments other than a selection of different operating, reliability, or manning scenarios that represent a modified system designed to offset high manpower demands or costs.

In reviewing the Army MPT problem outlined earlier in this section, it appears that a technique such as the HCM could certainly contribute to resolving most of the man-machine mismatches with new acquisitions. Ultimately, it is the Army's primary intent to use the results of such an approach to influence the ASARC, DSARC, and system program management communities to be more supportive of the MPT portion of system-integrated logistics support. At a secondary level, it is also the Army's desire to examine techniques such as the HCM with the intent of determining the feasibility of enhancing and managing its own MPT system. For both the ASARC

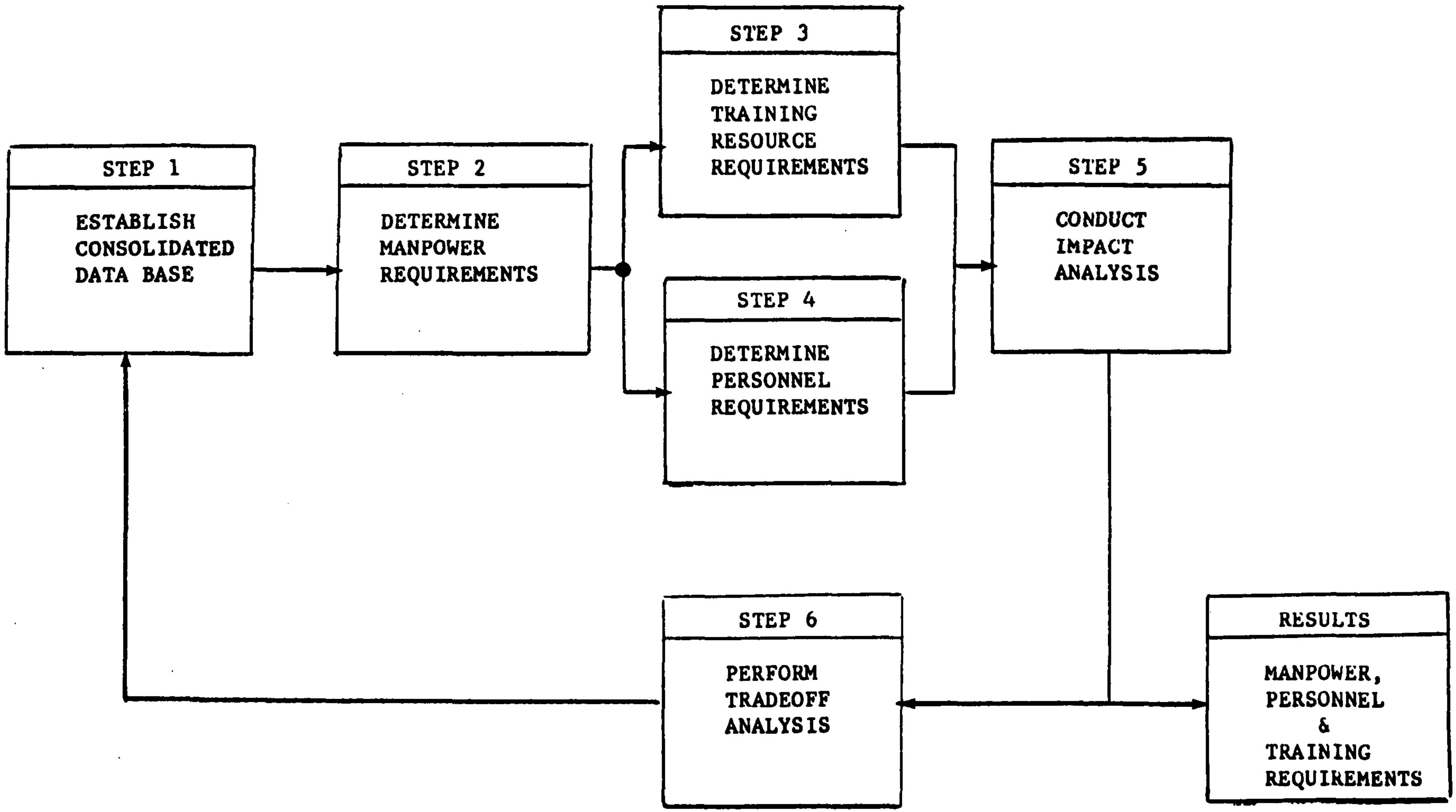


Figure 2-1. Steps in Application of the HARDMAN Methodology

decision and internal MPT management objectives it is important that the Army establish a credible MPT projection scheme. It then follows that any anticipated MPT projection techniques be validated before being approved for Army-wide use. The following section describes the structure for the HCM validity evaluation and sets the foundation for the final results provided later in the report.

SECTION III

STRUCTURE OF HARDMAN ANALYSIS

A. OVERVIEW

The previous section described how important it is for the Army to develop a credible, comprehensive MPT system. There are several different kinds of validity tests to consider when establishing the true credibility of a modeling technique. For example, some kinds of mathematical models may obey other already proven algorithmic or empirical relationships. Validating techniques using this method is rather simple. However, the problem becomes more difficult when a proposed simulation is projecting the future based on experiential judgment and scant, or non-existent, historical evidence. As shown in Section II, the proposed Army MPT methodology not only fits this description but is further complicated by the need to draw on a considerable amount of data and data sources. In situations such as this there are several different kinds of validity tests that can be employed to test "first-time" models. In this section the various kinds of validity tests are first described, followed by a detailed discussion of the structure of each portion of the evaluation in the context of the validity tests.

B. VALIDITY TESTING

The two important outcomes of testing the validity of a simulation or projection are the degree of credibility of the model and results, and the respective usefulness of the results. The credibility of a projection methodology revolves around several operations research-type measures. Two very important validity measures are as follows:

(1) Variable parameter validity - a measure of how well the simulation parameters compare with their respective counterparts in the real, or observable, world; and whether the parameters, when varied over an expected range, effect the results in the direction of known historical data.

(2) Hypothesis validity - a measure of how well various relationships within the model and its outcomes correspond with the real world.

Both of these validity measures fit under generic tests of "model accuracy." As stated earlier in Section I-B, the detailed accuracy examination has been postponed to a later phase.

Within the constraints of this study, the following validity tests were exercised:

(1) Face validity - a general indication of whether the model is logical, credible, and the results reasonably based on the inputs.

This indication can be obtained by talking to individuals experienced with the same, or similar, models; comparing the structure of the model to other established simulations; or tracing and evaluating test case results for reasonableness.

(2) Internal reliability - a measure of the variance in model outputs when replicated by a group of independent assessors given the same inputs.

(3) Event series validity - It is understood that inherent within the design of any model is the inability to duplicate exactly the real world. Event series validity is a measure of how accurately the simulation must reproduce real-world events. This test is extremely important because it relates to both the credibility and utility of the results as viewed by the people using the outputs for their decision process (i.e., the ASARC and Program Managers).

In the following paragraphs, the various analytic procedures employed in evaluating the Army MPT methodology are discussed in terms of the preceding validity tests.

C. USER REQUIREMENTS ANALYSIS

One of the more obvious tests of face validity is a straightforward, initial comparison of the user needs against the outputs of the model. By querying knowledgeable individuals in the Army MPT arena for problems, and their respective needs to resolve those problems, it was possible to evaluate whether the proposed methodology could illuminate the key personnel issues. The effort designed to establish the relevance of the HCM MPT system to the Army's needs was fourfold:

(1) Establish a list of experienced, interested individuals from the Army MPT community and attempt to draw on individuals from as many participating commands as possible to establish a broad user base.

(2) Design a comprehensive set of questions to probe both major MPT problem areas and needed solutions and/or tools to resolve personnel issues.

(3) Obtain answers to these questions via personal interviews with each individual.

(4) Compare the results against the applicable portions of the methodology to establish whether HARDMAN is reasonably responsive to the stated issues.

Each step in the above user analysis, along with both the user requirements and relevance results, is discussed in greater detail in Section IV.

D. OPERATIONAL ANALYSIS

As a continuation of the face-validity evaluation, it is also useful to examine applications of the methodology as a means of establishing credibility. In this study the examination encompasses both actual test cases and comparison with other accepted or proven MPT projection techniques. The structure and results of both of the aforementioned examinations are provided in greater detail later in Section V. However, as a basis for the outcomes provided in Section V, it is important to note that the results afforded insight into several credibility issues. First, the results provided information on how rational the model was. For example, the test-case audits were established to examine the consistency and reasonableness of the results relative to the inputs. Similarly, by comparing the technique against other accepted models, it was possible to see whether the basic assumptions and logic structure appeared sound. Second, the audit results provided useful information on the complexity, and subsequent utility, of the model. Third, the audits provided an understanding of whether the model logic and interpretation of the projections were perhaps ambiguous or masked, due to model over-complexity. Fourth, the audits indicated the presence and relative occurrence of error sources in the methodology. Last, the use of both test cases and comparisons with other MPT models highlighted potential problems in input data quality and availability.

E. RELIABILITY ANALYSIS

An examination of the "reliability" or accuracy of the methodology and its projections was the original intent of this portion of the evaluation. Although it was possible to retain part of the original reliability analysis scope, time and funding constraints required the actual accuracy effort to be postponed until the next evaluation phase. The portions retained for this part of the evaluation address the issues of internal reliability, a precursory accuracy examination using the experience of individuals who have already applied the HCM, or a similar methodology, and event-series validity.

For the internal reliability test, it was decided to use one of the Army test cases (i.e., SINCGARS) and design a controlled experiment to establish whether a group of individuals, initially trained to use the methodology, could both replicate the original answers and demonstrate a low variance in answers among themselves. A group of seven individuals (four civilians and three career Army personnel) of varying backgrounds were selected for the experiment. Given the small sample size (primarily due to restrictions in available people, time, and budget) it was decided to dispense with detailed statistical comparisons and simply establish general conclusions about the repeatability and consistency of the results. The replication was also used to develop a list of critical factors that have major impacts on the MPT projections.

To round out the accuracy examination within the constraints of the study, it was also decided to perform a qualitative accuracy check, using past Air Force and Navy experience with the same type of methodology.

As stated earlier, the event-series validity test is extremely important for determining the required accuracy of a model and, subsequently, the utility of a new simulation. To obtain an estimate for the required accuracy of the HCM, a simple top-down cost sensitivity analysis was employed to establish the allowable variance in the manpower projection, as constrained by other life-cycle cost elements and an allowable error band around the total life-cycle cost projection. This estimate of the allowable variance in the manpower projection was performed for an example acquisition, using actual Army weapon system data (i.e., the SINCGARS system). Once the level of accuracy was established, it was possible to formulate corrective actions (for the various problem areas revealed through the face-validity and internal reliability investigations) commensurate with a greater or lesser need for accuracy. It was for this reason that the sensitivity test was reserved for the end of the evaluation. The complete details of the internal validity and accuracy studies are provided in Section VI.

SECTION IV

USER REQUIREMENTS ANALYSIS

A. OVERVIEW

As a part of the approach developed to determine the face validity of the HCM MPT projection model, an MPT user requirements study was conducted. This analysis included a definition and documentation of Army user requirements for a manpower, personnel, and training (MPT) prediction model. Subsequently, the user requirements were compared with the capabilities of the HCM to determine the degree to which the technique conformed with the needs of intermediate as well as end users of MPT information. The users included those who currently develop the MPT information as well as those who primarily use the information (Table 4-1). The details of the requirements analysis are provided in the following paragraphs.

B. APPROACH

This study focused on exploring Army user requirements for a "generic" MPT methodology that would serve as comparison against an existing MPT projection technique for the Army's Integrated Logistic Support (ILS) process. The user requirements provided a useful measure for determining the extent to which the HARDMAN model fulfilled the Army's stated requirements. As stated earlier in Section III-D and III-E, detailed audits and a test case replication were also conducted to assess face validity and internal reliability. The additional familiarization with the HCM technique achieved through these parallel analyses augmented the comparison of the user requirements with the methodology.

The basic approach, outlined in the preceding discussion, is explained in greater detail in the following paragraphs:

1. Selection of Individuals

The Interim Report for Manpower and Personnel Requirements Determination Methodologies (MANPERS) states that "the three principal organizations responsible for the research, development, and deployment policy of a system under development are DARCOM - the materiel developer; TRADOC - the training and doctrine (i.e., combat) developer; and HQDA - the force modernization planner. With the exception of the "industry" user, all of the users interviewed in this study were from these three organizations in the Army. These commands were also confirmed by the sponsoring agencies (Army Research Institute (ARI) and the Soldier Support Center (SSC)), as key actors in the Army's MPT process.

A predominance of users were from the TRADOC community. This is a reflection of the fact that "front end analysis," such as MPT projections, done prior to Phase I in the systems acquisition process, is largely a TRADOC responsibility. TRADOC has the lead in ILS management prior to the appointment of a DARCOM Project Manager at Milestone I.

Table 4-1. User Groups/Representatives Interviewed

Users	Number of Interviews
ILS Managers (DARCOM)	2
Soldier Support Center/SSC-NCR (TRADOC)	3
Logistics Center/LOGCEN (TRADOC)	1
Deputy Chief of Staff, Combat Development/DCSCD (TRADOC)	1
Deputy Chief of Staff, Training/DCST (TRADOC)	2
Special Study Group-TRADOC Systems MGR/SSG-TSM (TRADOC)	1
Logistics Evaluation Agency-DCSLOG/LEA	1
DCSPER	1
Industry (based on results of survey)	1
Total User Groups: 9	Total Respondents[a]: 13

[a]Users listed were selected on the basis of their role/function in the MPT process. All users contacted participated.

Inputs from the SSC-NCR-II (TRADOC) and industry users were not gathered from actual interviews. The information needed from these users was not obtainable within the allocated time frame for the study and was, therefore, extracted from documents that adequately portrayed their respective user needs for an MPT projection model. One document was a memorandum about requirements for an MPT model (9) and the other was an industry survey conducted by the Soldier Support Center to determine industry requirements for MPT information in developing proposals (10).

2. Questionnaire Design

The questionnaire was designed as a discussion guide to identify user requirements. Some questions addressed user requirements directly by identifying the specific MPT information input they require to fulfill their responsibilities for the Army MPT process. Other requirements directly addressed were imbedded in questions concerning the user's interpretations of the timing and interfaces required by the process. Through interface and timing questions, an understanding was developed about when critical MPT information is needed and about the relationships between principal organizational players, so that it could be determined if the design or structuring of an MPT projection system would be sensitive to these relationships. Another direct way of focusing on user requirements was to ask respondents for

suggestions about the design of an MPT methodology. Suggestions included comments on outputs, schedule, and the process of actually projecting personnel needs. Questions indirectly addressing user needs provided confirmation, context, or further elaboration of the direct user data. These questions referred to the following contextual information:

(1) The user's understanding of the present technique used for MPT projections.

(2) Users seen as responsible for MPT projections and the nature of their "use" of the information (intermediate or end use).

(3) MPT regulations/documents that impact the user.

(4) Users' perceptions of the strengths or weaknesses of the current MPT process.

(5) The primary charter and responsibilities of the user.

(6) The key drivers underlying the need for MPT projections, according to each user interviewed.

The complete questionnaire is shown in Appendix A.

3. Interview Procedure

User requirements were determined primarily through interviews with the representative users who were identified and recommended by the sponsor. Initial contacts made by ARI provided JPL with direct access to appropriate individuals with whom formal follow-up requests for assistance were made and visits scheduled.

The study received a substantial level of user cooperation in conducting the interviews; an example was that users frequently called upon people within their organizations having specialized knowledge of that organization's involvement in the MPT process. Each scheduled interview was treated as a single-user interview even if more than one person was present for the discussion. A single-interview form consolidated the responses of all present from that organization.

C. TABULATION OF INTERVIEWS

1. General Responses

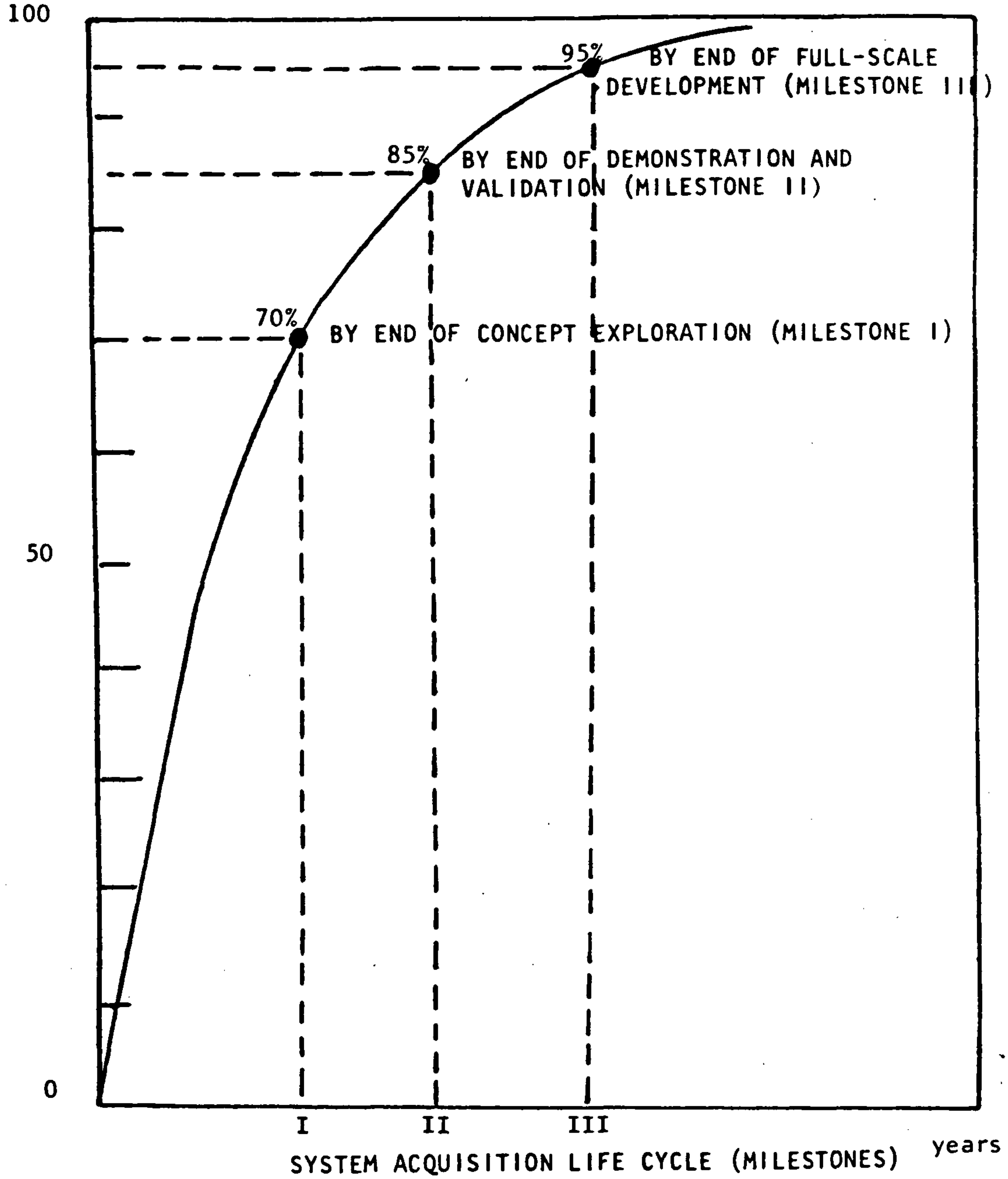
Most of the users interviewed thought that MPT projections should be available at the front end of the acquisition cycle. This was frequently linked to <u>supportability</u> and <u>affordability</u> drivers for needing MPT information, particularly because these affect the user organization's roles and responsibilities for MPT projections. One user cited <u>sustainability</u> as a key driver of MPT information. This was considered an important insight because it highlights life-cycle aspects of system operation. The predominant responses pertaining to these three major drivers are summarized in Table 4-2.

Table 4-2. Key MPT Drivers and Associated User Rationale

Key MPT Drivers	Predominant Rationale
Affordability	MPT system must provide all MPT cost elements associated with acquisitions
	MPT system must reflect cost tradeoffs with force structure/mission requirements
Supportability	MPT system must support readiness goals
	MPT system must fully support new acquisitions (operations, maintenance, supply, training, etc.)
	MPT system must demonstrate sensitivity to horizontal MPT impacts (Integrated System Support concept)
Sustainability	MPT system must support manning/training system(s) plans over long periods of time
	MPT system must consider extended impacts of mission/ scenario changes with time

Most users expressed the idea that system design should be influenced by various manpower constraints emerging from early MPT analysis before the design is fixed. A related point is that most users thought that the primary tool for getting MPT projections into the system through the Quantitative and Qualitative Personnel Requirements Information (QQPRI), which is developed concurrently with the Basis of Issue Plan (BOIP), was inadequate and/or untimely. By the time QQPRI data is available (after Milestone I), most of a system's design is fixed (Figure 4-1). Another problem mentioned was that DARCOM and TRADOC's shared responsibility for developing the QQPRI and BOIP requires additional clarification of lines of responsibility. This would be particularly important if the initial development of MPT projections shifts to an earlier point in the acquisition cycle (i.e., TRADOC would become responsible for the initial, therefore tentative, QQPRI).

Occasionally, a user expressed a viewpoint that MPT projections made later in the acquisition cycle were adequate, providing that sufficient lead time was given to acquire and train the personnel. This statement assumed that funding was already available for the personnel.



SOURCE: Proceedings from National Security Industrial Association Symposium on Navy Systems Acquisition, October 27-28, 1977.

Figure 4-1. Effect of Design Decisions on Life-cycle System Cost

2. User Group Responses

User responses are reviewed in this section. Responses from multiple users in DARCOM and SSC-NCR are incorporated under single headings for these respective organizations. Individual responses, by organization, are detailed in Appendix B. The discussion on user responses includes a summary of the user organization background to establish the appropriate context for the responses that follow.

a. DARCOM/Integrated Logistic Support (ILS) Managers Responses. ILS managers in DARCOM are responsible for ensuring the planning and monitoring of logistic support elements for systems under development from Milestone I throughout the development process. The prime analytical tool used in ILS is Logistic Support Analysis (LSA).

The LSA process consists of analysis efforts to completely define the support system and its interfaces with a materiel system. The analysis incorporates manpower/logistics analysis and tradeoff analyses associated with maintenance concepts (repair levels, etc.). LSA Record information (LSAR) includes all tasks required to operate and maintain a materiel system. LSA data then becomes feeder data for the Quantitative and Qualitative Personnel Requirements Information (QQPRI) system. As the chief means of developing both the numbers and kinds of personnel required for operating and maintaining systems, QQPRI development is a shared responsibility of DARCOM and TRADOC. As a result, LSA data needs to be as accurate as possible for both the DARCOM and the TRADOC user communities.

LSA normally includes operator/maintainer task and supply functions for repair and test equipment as well as the system under development. In determining system supportability, ILS managers required information about the exact tasks to operate and maintain systems. They also needed projections of reliable manloading requirements to help establish expected Military Occupational Specialty (MOS) and skill demands, plus any MOS changes anticipated.

ILS managers stated a need for methods to analyze tradeoffs between force structure, personnel constraints, hardware performance, and cost. Essential to this analysis was information (output) about support and test equipment ("playing field") associated with a system. The total QQPRI associated with an expected density of these systems, when deployed, was cited as an important element of this analysis.

Early maintenance concept information was also requested, including maintenance manhours (MMH), reliability, availability and maintainability (RAM) data, and maintenance-level information.

DARCOM suggestions for the design of an MPT model included providing/displaying MPT data for alternative (proposed), as well as predecessor systems to provide support documentation for decision-making. An MPT methodology would need to provide credible quantitative data to the ILS process, the source(s) of which could be documented or traced. Formats for the data should be designed to present data efficiently to users who have limited time for reviewing information (e.g., graphs, charts, etc). Timing for initiating the process should be prior to Milestone I to achieve maximum benefit from

hardware/manpower tradeoffs; however, there should also be follow-up on existing systems in the field to verify LSAR data and system supportability information.

b. SSC-NCR (TRADOC) Responses. SSC-NCR is responsible for assessing the feasibility of allocating personnel and materiel to specified organizations within the Army (i.e., the Tables of Organization and Equipment (TOE). SSC also ensures that the user communities identify both demand and supply MPT factors at the front end of the system acquisition process to address supportability and affordability issues.

SSC-NCR stated that detailed data for the following general categories of information is required:

(1) Manpower.

(2) Comprehensive task breakdown.

(3) Personnel.

(4) Training.

(5) Logistic support.

(6) Integrated System Support (ISS).

Graphic display capability was highlightd as useful to SSC for inclusion in reports comparing demand and supply. In addition, detailed MPT analyses comparing proposed to predecessor systems is required.

SSC also needed MPT projections prior to Milestone I to support the Army Systems Acquisition Review Council (ASARC) decision process. An additional need cited was timely and useful cost information for the Army's funding process. In providing such information, the projection process should also expose any assumptions employed so that an understanding of the limitations of the analysis is clear.

SSC-NCR further suggested using a solid, historical data base containing Army personnel statistical data, comprehensive task-related files, and RAM data associated with systems. It was also indicated that the MPT system should be compatible with existing Army reporting structures and command roles to ensure that the model could be integrated into the Army's normal systems acquisition process.

c. Training Developers (TRADOC) Responses. A key concern of training developers within TRADOC Headquarters is the integration of the Army's training function with the other critical Army functions - manning, force structure, facilities, equipping, sustaining, mobilizing, and deploying. Matching the Army training system to manning and the systems acquisition process is crucial to the support of force modernization. Supportability of force modernization requires specific information about the availability of manpower qualified for training, as well as sustainability (personnel flow and replacement) of the force required.

Another driver of training developers' needs for MPT information was system affordability, i.e., an understanding of a system's life-cycle cost. The general categories of information needed by training developers to determine supportability and affordability were (1) manpower and personnel information (demand/supply); (2) training information (exact operator/ maintainer task and target audiences); (3) equipment information (capability and man/machine tradeoffs); and (4) accurate maintenance concept information.

d. Combat Developers/Soldier Development Directorate (SDD) and TRADOC) Responses. Combat developers in TRADOC/Soldier Development Directorate are concerned with personnel doctrine that addresses air/land battle mission needs. They also promote combat effectiveness through MOS and force structure change and ensure that soldiers' physical and mental capabilities are taken into account by the various elements of force modernization. In their interface between SSC and TRADOC Headquarters, combat developers at SDD are involved in the process of optimization of resources between proponent schools.

The combat developer's key drivers for needing MPT information were supportability, in a readiness sense; performance, as it relates to combat effectiveness (e.g., through man/machine design issues); and cost (e.g., as might be determined by impact analysis).

Combat developers' design suggestions focused on the need for an interactive management information system having a time-line signaling mechanism that could alert participants to needed (or missing) actions in the current MPT process. Suggested outputs from the MPT model were a projection of the numbers and kinds of operators and maintainers associated with a system. A timely breakdown of task and training data was also cited to influence system design (prior to Milestone I).

It was also suggested that some information concerning the impacts of new systems on the existing personnel structure and resulting tradeoffs would be useful in optimizing the selection of new systems. This requirement also implies a need to apply MPT analysis to systems on a horizontal plane (i.e., to consider the drain on the projected manpower pool caused by other developing systems).

e. Tradoc System Managers (TSM) Responses. During the gestation period of a system prior to Milestone I, TRADOC assumes the lead in conducting mission area studies. A TRADOC Systems Manager (TSM) is concerned with the identification, analysis, and selection of system concepts that meet needs of combat elements of the Justification of System Major New Starts (JSMNS) document. Other responsibilities of the TSM include preparing the Operational and Organization (O&O) plan, as well as monitoring the preparation of a number of different documents required for logistic support. Among these are (1) the Integrated Logistic Support Plan (ILSP); (2) the Concept Formulation Package (CFP); (3) the Outline of Individual and Collective Training Plan (OICTP); (4) the Letter of Agreement (LOA); (5) the Cost and Operational Effective Analysis (COEA); and (6) the Preliminary Qualitative Assessment (PQA). The

Preliminary Quantitative and Qualitative Personnel Requirements Information (PQQPRI) could, by interpretation of the current regulation, be initiated by the TSM although it is not normally done at this time.

The TSMs had a clear requirement for a model that would contain a comprehensive task file data base with task data taken from a number of task-centered Army manuals and documents. This would assist the TSMs in ensuring the timely completion of these documents by facilitating the identification of specific tasks, MOS, and skills associated with hardware. Finally, the TSMs suggested the development of both a manpower and personnel (demand/supply) data base that would permit tradeoff analysis to determine the best fit of people with equipment.

f. LOGCEN/LOGISTICS CENTER (TRADOC) Responses. Force developers, training, and materiel systems managers are all MPT actors within LOGCEN. The critical role of LOGCEN is as an executive agent for the ILS process. Issues such as man/machine interface, system and non-system training devices, logistic system proponency, and Manpower Authorization Criteria (MACRIT) are included in LOGCEN's charter. Some of the LOGCEN responsibilities are (1) impact analysis of system/design characteristics; (2) support equipment training plan and technical publications development; and (3) MACRIT system improvement. As a TRADOC integrating center, LOGCEN is similar to a proponent school in its proponency role for selected logistic systems. LOGCEN also develops some TOEs for maintenance units.

LOGCEN indicated they had specific information requirements related to system considerations for affordability and supportability, including (1) accurate RAM data (based on historical data and accounts for realistic utilization rates, actual failure rates, and combat damage); (2) workload data (as a function of direct productive and indirect productive annual maintenance manhours (AMMH), plus available productive manhours); (3) density of equipment (TOE-related); (4) unit-focused manpower requirements; and (5) LSAR-format task data associated with MOS and equipment needed for training analysis.

LOGCEN's MPT timing requirements were twofold: (1) LOGCEN needed early (front-end) training device information to prepare for both early system testing and the final system design configuration, as well as (2) solid manpower requirements for supporting accurate MOS and organizational design decisions.

Design discussions about MPT projection models focused on LOGCEN's requirement for accurate and reliable (RAM) data. The Annual Maintenance Manhour (AMMH) data that LOGCEN presently receives should be made separate and distinct from reliability data. MPT information was needed in an LSAR data format and would be more useful if broken down by component, task, and skill level. It was felt that this could then be used with an MPT simulation to determine impacts of utilization rate, combat damage, and/or hypothetical changes in RAM characteristics.

A concern was expressed about the accuracy of data to be used for MPT analysis. The availability of "hard" LSAR data is critical to the development of useful MPT information. Given an absence of system fielding experience and

correspondingly mature LSAR data (such as would be the case when substantial technological changes in equipment are introduced), it was recognized that it would be difficult to obtain reliable data. However, it was also recognized that, if there is minimal technological change, the MPT information should be readily available.

g. Devices and Systems Training Directorate (TRADOC) Responses. This organization is involved in policy development, training-device proponency, and training-plan approval.

In general, this directorate indicated needs for both manpower and training information for the purpose of developing the individual and collective training plans (ICTP) of systems under development. A new Army thrust called Integrated System Support (ISS) now requires the generation of MOS information that is system- as well as unit-specific. It was also suggested that an improvement to the current MPT process would be to provide sufficient front-end task manloading and training information to allow the design to be influenced early in the acquisition process. One final expressed requirement was to have an MPT projection model that more effectively flags MOS "overload" (i.e., a model that detects and documents additional needed manpower, both numbers and skills).

h. Logistics Evaluation Agency - LEA (DCSLOG) Responses. As a field-operating agency of the DA staff, LEA is the independent logistician in the materiel acquisition process responsible for monitoring ILS requirements for systems under development. Supportability of the more than 800 systems to be evaluated was cited as a key driver for needing MPT information, along with other factors such as degree of interoperability and performance levels.

LEA users indicated a need to be able to use MPT projections (before Milestone I) as constraints during system development. These MPT projections should include RAM goals, new skills and training device concepts. Following Milestone I, it was suggested that readiness considerations include a 3- to 5-year lead time to acquire and prepare logistic support personnel prior to system fielding. LEA information requirements also included a complete and accurate listing of tasks and skills required to maintain the system (including all subsystems). Finally, there was an expressed requirement to look across systems (horizontal analysis) to assess overall impact on logistic support and training.

i. Force Modernization Cell - Manpower Programs and Budget (DCSPER) Responses. This organization provides staff support to DCSPER for the Army Systems Acquisition Review Council (ASARC). They are chiefly concerned with resource management for force modernization and bridging demand and supply issues in both manning and force-structuring. DCSPER is concerned with matching the number and kinds of "spaces" needed to operate and maintain systems with the required qualified personnel (i.e., "faces"). In this respect, they are also concerned with the personnel training. Because of congressionally-mandated "end strengths" for the Army, information concerning distribution of personnel is important. Recognizing that affordability and

user supportability concerning the supply of personnel is a realistic constraint, DCSPER therefore suggested that a horizontal look across systems would permit analysis of the impacts of shifts in the numbers and types of manpower required. Tradeoff analysis at a high level was also cited as useful for conducting Army-wide optimization studies (e.g., hardware vs. manpower vs. system performance).

Finally, it was indicated that the design and output of an MPT model should be compatible with existing reporting processes (QQPRI, BOIP, ASARC Milestones, etc.). In line with this requirement, it was also suggested that there is a need for a more effective (interactive) information system, with appropriate access to relevant data bases of MPT information.

j. Industry Responses. Three industrial associations (Aerospace Industries Association, Electronic Industries Association, and National Security Industrial Association) were surveyed about their needs for logistic support (MPT) information in responding to Requests for Proposals (RFPs). It was discovered that industry is very interested in improving its understanding of logistic support and human factors concepts associated with systems under development. Some suggested means to accomplish this were (1) earlier user contact, (2) user involvement in RFP preparation, (3) better implementation of human factors analysis, and (4) improved information dissemination to industry. Two basic concerns of industry have been to address human factors before the system design is fixed and to specify contract arrangements for implementing MPT analysis.

Industry also indicated a need for reliable information concerning the intended/planned concept of system operation and supporting organizational design. The participants also suggested DOD strengthen its estimates of the kinds of personnel expected to operate and maintain the system. Scenarios depicting both threat, environment, and realistic usage rates were cited as important in preparing RFPs. The expected performance of a system, plus maintenance concept, were two other critical data points contributing to industry's ability to conduct or contribute to early MPT analysis.

The industry-users interviewed also indicated a need for MPT information to be centrally located for accessibility. Charts and graphs were suggested as being especially helpful in transmitting to industry the necessary information. An historical data base was also suggested to permit comparisons with other developed systems or analysis of system designs that were rejected.

2. Tabulation of Individual Interviews into Matrix Format

After all user interviews were completed, the raw discussion notes were assembled, reviewed, and transcribed onto interview forms for clarity. Key words and ideas were highlighted. Two requirements analysts then separately analyzed the information and jointly tabulated the responses to facilitate analysis of the results. Once the answers were transformed into rough requirement statements, they were entered into a matrix format to permit a clear indication of which users were associated with each user need. The detailed matrix of users and user answers is shown in Appendix B.

D. TRANSLATION TO USER REQUIREMENTS

1. Procedure

The user needs were divided into two categories - one category containing "output" (data) needs, and the other containing "design" needs for an MPT projection system.

User requirement statements were generated from the Appendix B matrix information and the interview forms. When appropriate, similar ideas or requirements expressed by different users were translated into a comprehensive user requirement statement.

The separate requirement statements developed by both analysts were then compared to ensure agreement and completeness. To establish priorities among the requirements, criteria were developed to evaluate the requirements in the matrices. A final user-requirements list was developed after applying these criteria.

2. Criteria for Assigning Priorities

The following criteria were considered essential to determine which requirements were necessary or desirable for an MPT projection model:

(1) The requirement's role in addressing key drivers associated with MPT projections for Army systems (i.e., affordability, supportability, and sustainability).

(2) The importance of the requirement in providing useful and timely MPT information to the Army system acquisition process.

(3) The breadth of users stating the requirement.

3. Requirements List

As stated earlier, the user needs were categorized by "output" and "design" needs and then prioritized according to the degree of fit with the three criteria stated previously. Once this procedure was completed, the user needs were grouped into mandatory and desirable requirements. Below is the final list of user requirements (including output and design requirements) for a projection system that conforms to the needs of the key Army players in the MPT arena. For the purpose of this evaluation, all the following mandatory requirements were given equal weight because, ultimately, they were primarily used to test the "reasonableness" of the methodology:

(1) Mandatory Output Requirements:

(a) Operator/Maintainer task data should be provided as required for a system and its support equipment (including task description and frequencies), based on a replaced or comparable system.

(b) Maintenance manhour projections must be based on a specified maintenance concept (levels of maintenance, specific RAM data).

(c) Operation and maintenance manpower, personnel, and training (MPT) projections must reflect realistic system usage rates as determined by acquisition-specific mission/scenario drivers.

(d) Reasonably accurate (i.e., acceptable to the budget-control community) total manpower demand (number, MOS, skill level, additional skill indicators) is required before Milestone I.

(e) The MPT model must include and document projected availability of personnel for the system (demographic data such as number, age, sex, size, skills, education, MOS, term of service).

(f) The MPT model should document MOS alignment data showing current status; authorizations vs. requirements to indicate MOS overloads.

(g) The model must incorporate, document, and use target audience description (TAD). This includes reading ability, grade levels, experience, skills, and previous training of available personnel to determine accurately testing/training requirements (the TAD would be input to the Letter of Agreement).

(h) The "T" of MPT must include the formulation, description and use of comprehensive training concept elements: (1) classes or training required (including any increases) for unit or institutional training; (2) time to train; (3) training frequency; and (4) training support (devices, facilities, instructors).

(i) There must be documentation of MPT impacts and costs on the Army as a whole.

(j) Trade-offs must be conducted between hardware and people to determine the optimal balance for best system performance, costs (LCC), and support requirements (Decision/Tradeoff matrix needed).

(k) Output should include reports with well-labeled, easy-to-read graphic formats such as graphs, tables, matrices, charts, as well as an executive summary of the report that could stand alone.

(l) Outputs should be in both hardcopy as well as on CRT display for permanent archiving.

(m) Reporting procedure must include any pertinent caveats about the data source availability/reliability or assumptions about the system. This information should be provided at major decision points or steps in the analysis. Appropriate actions to resolve identified weaknesses in the analysis should also be noted.

(2) Desirable Output Requirements:

(a) A complete historical MPT data base is highly desirable. MPT projections should be updated throughout the life of the system to increase accuracy of LSA/ other data.

(b) MPT impacts should account for geographical constraints on manpower pools "available" to run the system.

(c) MPT system output should be compatible with accepted LSA reporting format.

(3) Mandatory Design Requirements:

(a) Projected MPT impacts/costs must be available at the front end of the acquisition cycle (before Milestone I) for early design influence and early MPT (cost) warnings.

(b) Front-end determination of a system's candidacy for MPT analysis should include criteria such as the potential for high payoff (e.g., selection should be based on type and amount of change in the technology that drive significant MPT costs/changes).

(c) To facilitate training analysis and to support proponency for MOS changes or additions, the system should have the capability to compare the proposed operator and maintainer tasks associated with a new system with a comprehensive, automated data base of tasks detailed in the Soldier's Manual, ARTEP, POI, SQT, T.G. and AR 611-201 (Enlisted Career MOS Management Fields).

(d) Output should include comparable MPT projection data for both alternative/proposed and existing systems as support for decision milestones.

(e) The model should incorporate horizontal analysis across systems to determine total MPT and logistic impacts and to facilitate Army-wide equipment and personnel optimization, as well as support end-strength decisions.

(f) The MPT model should provide compatability with existing DOD documentation and reporting structures. It should, however, evolve into an interactive

information system with remote terminals, including a time line oriented to both the budget and systems acquisition processes. Signalling mechanisms are needed for late/missing/incomplete data.

(g) The MPT system must identify and provide resolutions to both weaknesses in data inputs and inaccuracies resulting from the use of the data.

(h) There must be a documented and accessible audit trail.

(i) A universal information system should be designed to allow multi-user access and update.

(4) Desirable Design Requirements:

A more detailed O&O plan is needed to act as a "hingepin" to initiate MPT analysis at the front end of the acquisition cycle.

E. RELEVANCE OF USER REQUIREMENTS TO EXISTING HARDMAN DESIGN

Having stated the user requrements in the preceding section, it is now possible to determine the extent to which the HCM has application to the requirements for the Army's existing (or near-term) MPT process. Through a comparison of the HCM to user requirements, it was possible to establish one measure of the face validity of HARDMAN (i.e., how well the HCM fits the Army's MPT needs). This was achieved by checking the relative applicability of each step in the HCM to specific portions of the requirements. As stated earlier, both the ARI replication exercise and the HARDMAN applications audit were conducted in parallel with the requirements analysis. These parallel studies afforded an in-depth understanding of each step in the methodology. The additional familiarization with the complete array of data inputs, algorithms, methodology logic process, and outputs, provided the essential background to perform a comparison. Table 4-3 presents the results of the compatibility analysis by indicating which portions of the HCM have high, medium, or low applicability to the user requirements. The degree of applicability provided an indication of the utility of various portions of the technique to the Army's MPT users.

Out of the thirteen total mandatory output requirements, the HCM demonstrated good compliance in essentially six of the user need areas. Of the seven requirements where elements of the methodology appeared to exhibit low applicability, only five of the user areas were considered of immediate importance to developing a sound MPT projection scheme. These key user areas were (1) establishing the accuracy of the MPT methodology; (2) including other demographic data such as age, sex, size, etc., in personnel allocations; (3) considering the demands of possible future acquisitions on MOS, (4) performing a complete life-cycle cost analysis as part of the tradeoff studies; and (5) indicating weaknesses in the analysis and respective resolution actions. Items (2) and (3) appear to be somewhat of an Army-wide constraint resulting from the general lack of readily available information. Therefore, only requirements (1), (4), and (5) seem to be achievable, close-range deficiencies that should be incorporated as improvements to the HCM.

Table 4-3. Comparison of User Requirements to the HARDMAN Comparability Methodology

User Requirements	Applicability of HCM Technique to User Requirements		
	High	Medium	Low
<u>Manadatory Output Requirements</u>			
Operator/maintainer task data as required for system and support equipment (description/frequencies) based on replaced or comparable system	X (Primary System)	X (Support Equipment)	
Maintenance manhour projections must be based on specified maintenance concept (levels of maintenance, accuracte RAM data)	X		
Operation/maintenance requirements must reflect realistic system usage rate as determined by mission/scenario drivers	X		
Reasonably accurate total manpower demand estimate (number, MOS, skill level, additional skill indicators) required <u>before</u> Milestone 1	X (Manpower demand)		? (Accuracy unknown)
Model must include and document projected availability of personnel for the system (Demographic data such as - number, age, sex, size, skills, education, MOS, term of service)	X (No., skills, MOS, Term of service)		X (Age/sex/ size education)
Model should document MOS alignment data showing current status; authorizations vs. requirements to indicate MOS overload	X (Current system demands)		X (Future, multi-system demands)
Model must incorporate and document target audience description - including reading, grade levels, experience, skills, previous training of available personnel to accurately determine testing/training requirements (would be input to Letter of Agreement)	X (Model assumes predecessor training is adequate		

Table 4-3. (Cont'd.)

User Requirements	Applicability of HCM Technique to User Requirements		
	High	Medium	Low
Manadatory Output Requirements			
The "T" of MPT must include the formulation, description and utilization of comprehensive training concept elements: classes required (including any increases) for individual; unit or institutional training: time to train; training frequency; and training support (devices, facilities, instructors)	X (Institutional training		? (Collective unit training)
Documentation of MPT impacts and associated costs for MPT projection	X		
Tradeoffs between hardware and people needed to determine optimal balance between performance: costs (LCC) and support requirements (decision/tradeoff matrix needed)		X (Limited tradeoff capability)	X LCC and other O&S elements)
Output should include well-labeled, easy-to-read formats such as graphs, tables, matrices, charts, as well as an Executive Summary of the report that can stand alone		X (Executive Summary)	
Outputs should be in hardcopy as well as CRT display for permanent archiving		X (Hardcopy)	X (CRT)
Reporting procedure must include briefing re: any pertinent caveats about the data source availability/reliability or assumptions about the system, at major decision points or steps in the analysis. Actions should be noted to resolve weaknesses identified		X (Not consistently done)	X (Resolution actions on major weaknesses)

Table 4-3. (Cont'd.)

User Requirements	Applicability of HCM Technique to User Requirements		
	High	Medium	Low
Desirable Output Requirements			
Historical MPT database highly desirable. MPT projections should be updated throughout life of system to increase accuracy of LSA/other data	X (Historical database)		X (Update over system life)
MPT impacts should account for geo graphic constraints on M.P. pools "available" to run the system			X
MPT system output should be compatible with accepted LSA reporting format			X
Mandatory Design Requirements			
Projected MPT impacts/costs must be available at the front end of acquisition cycle (before Milestone I) for (a) design influence and (b) early MPT (cost) warnings	X		
Front-end determination of system's candidacy for MPT analysis should include criteria such as potential for high payoff, e.g., selection should be made on type and amount of change in the technology that mighttttdrive significant MPT costs/changes	X		
To facilitate training analysis and proponency for MOS changes or additions, the model should have the capability to compare operator and maintainer tasks associated with a selected system with a comprehensive automated database of tasks detailed in the Soldier's Manual, ARTEP, POI, SQT, T.E. and AR 611-201 (enlisted carreer-MOS Management Fileds)	X (New skill identification)		X (Automation)

Table 4-3. (Cont'd.)

User Requirements	Applicability of HCM Technique to User Requirements		
	High	Medium	Low
<u>Mandatory Design Requirements</u>			
Output should include comparable MPT projection data for alternative (proposed) and existing systems as support for decision milestones	X		
Should incorporate horizontal analysis across systems to determine total MPT and logistic support to facilitate ARMY-wide optimization and support end strength decisions			X
MPT model should provide compatibility with existing DOD documentation and reporting structures; however, it should evolve into an interactive information system with remote terminals, including a time line oriented to both the budget and systems acquisition processes. Signaling mechanisms are needed for late/missing/incomplete data	X (Existing documentation)		X (Remote terminals with time-line overlay)
MPT system must identify/resolve weaknesses in data inputs and resulting analysis			X
Documented and accessible audit trail is essential		X	
Universal information system (CDB) should be included and designed to allow multi-user access and update	X (Consolidated database)		X (User access)
<u>Desirable Design Requirements</u>			
More detailed O&O Plan required as "hingepin" to initiate MPT analysis at front end			X (Army responsibility)

Out of the nine mandatory design requirements, the technique seemed to be in reasonable agreement with seven of the user needs. The two areas where there was low agreement were considered critical for the near term. These two areas were, (1) consideration of the horizontal effects of other systems on the manpower drain and (2) construction of a means to flag and resolve weaknesses in the MPT analysis. Both Items (1) and (2) were already discussed as being an equally important consideration on the "output" side of the system.

Overall, this discussion suggests that the HCM is reasonably applicable to the Army's major user needs in its present design. More specifically, the present HCM basically meets seventeen of the twenty-two crucial user needs. Therefore, by being largely commensurate with the present user requirements, the technique seems to have considerable near-term utility to the Army.

SECTION V

OPERATIONAL ANALYSIS

A. OVERVIEW

Section IV provided one measure of face validity by indicating the relative compliance of the HCM with independently-derived user requirements. This part of the analysis suggested that the methodology had considerable utility to the Army. Other important face-validity considerations were introduced in Section III. These considerations refer more to the general integrity of the technique and include such elements as potential error sources, logic, reasonableness or credibility of the projected results, inherent ambiguities in the logic or outcome, and how supportable the model is by its respective input data sources. To close out these last elements of the face-validity analysis, a multi-leveled approach was structured, basically consisting of (1) a comparison of the HCM against any MPT modeling schemes delineated in existing DOD and MIL-STD instructions; (2) a comparison of the HCM against a host of other known MPT projection or modeling schemes; and (3) an independent, detailed, step-by-step audit of actual applications of the technique. This part of the overall study was termed "operational analysis" because every aspect of the methodology was actually exercised quite rigorously. The following paragraphs first provide the detailed rationale and approach used to investigate the various remaining face validity issues, followed by the actual analysis and conclusions concerning the "general" integrity of the HARDMAN system.

B. APPROACH

To ensure that the HCM was generally sound, beyond the user requirements compliance, several additional face-validity elements were considered. The additional face-validity elements and respective tests were as follows:

(1) Logic - A simple examination of whether the proposed technique maintains a well-structured, credible train of logic throughout the model.

(2) Usability - A simple study of both the utility of the model and the ease with which the model can be applied by others.

(3) Error Sources - An investigation of whether the methodology incorporates data inputs or internal procedures that can cause inaccuracies in the projections.

(4) Data Availability - A basic check on whether the modeling technique draws on real-world, available data sources to act as a foundation for the projections.

(5) Ambiguity - An examination of the ability of the model to be both consistent and succinct in its respective use of data and overall design (e.g., having each successive step build on previous steps). The ambiguity test also includes a look at how clearly the results relate to the model's original objective(s).

(6) Credibility - A simple test of whether the results seem reasonable, based on the inputs and whether the technique incorporates a means of weighing the quality of the data inputs and results.

A three-phased analysis was structured within the context of the preceding face-validity tests. The first and second phases of the analysis primarily addressed the logic, usability, error source, and data-availability elements. The third phase of the face-validity analysis encompassed all six of the above elements.

As an initial step in evaluating any new modeling scheme, it is useful to compare the new methodology against similar techniques that appear reasonable and/or are already tested and in use. This comparison serves several purposes in the context of the above first four validity elements. First, it provides a basis to examine whether the overall logic and structure of the model are reasonable. Second, the comparison establishes a yardstick against which to measure improvements in the versatility and subsequent utility of the model. Third, it assists in flushing out inherent sources of errors. Last, the comparison sheds light on the availability and quality of data.

To these ends, the first phase of the validity analysis examined existing DOD and MIL-STD guidelines to see if any credible MPT projection schemes have already been established. Similarly, the second phase consisted of conducting a much larger literature search inclusive of past and present MPT models from both the government and private sectors.

The third phase of the face validity study was a detailed audit of three applications of the projection technique. This part of the operational analysis proved to be a pivotal component because it encompassed all the validity insights provided by the above literature searches, as well as a grasp of (1) the ease with which the model could be applied by others; (2) whether the technique contained discontinuities between its inputs, internal mechanics and results (therefore introducing ambiguities); and (3) whether there was a clear indication of the quality and limitation of the outcomes. The three applications chosen for the audit were the Single Channel Ground Airborne Radio System (SINCGARS), Remotely Piloted Vehicle (RPV), and the Division Support Weapons System (DSWS). The results of the three remaining phases of the face-validity analysis are detailed in the following paragraphs.

C. ANALYSIS OF EXISTING DOD MPT PROJECTION GUIDELINES

As indicated in Section II, there are several DOD and MIL-STD documents that refer to MPT. For example, DOD 5000.1 and 5000.2 describe the structure and supporting procedures for planning and completing major system acquisitions (1,2). As a precursor to 5000.2, the 5000.1 directive calls out the necessity to define, estimate, and budget accordingly, MPT at the acquisition management level. The 5000.2 directive, acting in a supplementary role, more specifically addresses how the new acquisition will be evaluated against the various support parameters such as MPT. For example, using a top-down approach, it first defines the acquisition review council (DSARC or ASARC) advisory roles and then establishes both the content and approximate time frames for the major acquisition and system development review phases. From the standpoint of threat mitigation, affordability, and supportability, detailed guidelines are provided for developing the system acquisition and support strategy. The 5000.2 directive states the necessity to consider MPT needs under the "System Readiness, Support, and Personnel (ILS)" portion of the document. Although this subsection requires that MPT estimates consider both peacetime and wartime manpower demands, skills, costs, and training, it does not indicate a methodology to assist in making these estimates. Similarly, the 5000.1 directive provides even less distinct guidelines for determining, and budgeting for, MPT costs. Because MPT falls under the heading of Integrated Logistics Support (ILS), the next step was to examine directives more specifically related to system support. Perhaps one of the best of the family of directives associated with system support is MIL-STD 1388A (11). This MIL-STD states up front the requirement to develop human engineering and safety programs as part of the overall system support analysis plan. The document then proceeds to delineate key MPT variables and supporting data that must be considered to determine whether the proposed system meets manpower readiness, supportability, and affordability goals. These variables include (1) the number of systems to be supported; (2) missions per unit of time; (3) mission duration; (4) operating parameters (days, miles, hours, flights, etc.); (5) maintenance and transportation periods; (6) descriptions of system components and operating environment (in terms of their impact on MPT); (7) task descriptions; (8) costs; and (9) special support and test equipment MPT impacts. Additionally, MIL-STD 1388A requires that all the various support scenarios for each proposed design alternative be compared against each other to optimize the design selection.

As in the case of the previously described DOD directives, MIL-STD 1388 also fell short of providing an analytic structure for projecting new acquisition MPT demands. Although a dead-end from the analytic standpoint, MIL-STD 1388A did provide more depth on some positive characteristics of the HCM. These characteristics revolved around the reasonably close match between the DOD MPT guidelines and structure of the data inputs and outputs of the HCM. Because MIL-STD 1388 provided more specific guidelines on MPT support considerations than DOD 5000.1 and 5000.2, it was decided to probe one level deeper into specific Army directives having to do with MPT. At this final level it was anticipated that all key MPT variables and data elements would be defined along with the supporting analytic structure. Probably the most concise Army directive in the MPT area is Army Regulation (AR) 570-2 (12).

This service regulation, entitled the "TOE Manpower Authorization Criteria (MACRIT)," provides criteria and standards that help establish an "equitable relationship between services performed and types of personnel utilized." To achieve this match the MACRIT requires that system manpower studies be conducted and the results approved by the Deputy Chief of Staff for Personnel (DCSPER) for the Army. The studies must provide the number of direct workers necessary to effectively perform a specified work activity. Direct (actual task performance), nonproductive (sleep), and indirect (travel and task preparation) times must be considered in the manpower calculation. The MACRIT defines some approximate time factors for these three elements and ultimately provides a simple equation to calculate manpower. This equation is as follows (12):

$$\frac{\begin{array}{c}\text{WORKLOAD}\\ \text{(in direct and}\\ \text{indirect manhours per system)}\end{array} \times \begin{array}{c}\text{FORCE STRUCTURE}\\ \text{(in number of}\\ \text{systems to be procured)}\end{array}}{\text{AVAILABLE PRODUCTIVE HOURS}} = \begin{array}{c}\text{MANPOWER}\\ \text{(number of}\\ \text{people)}\end{array}$$

Figure 5-1 shows that the above expression can be depicted graphically as a rectangular function.

One interesting aspect of the MACRIT manpower equation is that the *number of support people is calculated for the complete procurement totally* independent of the acquisition time cycle. Therefore, if the manpower requirement per year was graphed as a function of the system life cycle, one would observe the same type of step function as shown in Figure 5-1, indicating no change in the manpower requirements over time. This function is discussed in greater detail later in this section. The most important aspect of the above discussion is that AR570-2 presently represents the key manpower projection and planning document in the Army. It is now also obvious, based on the HCM summary provided in Section II-B, that the methodology is strongly aligned with the manpower guidelines as specified in the MACRIT, as well as the

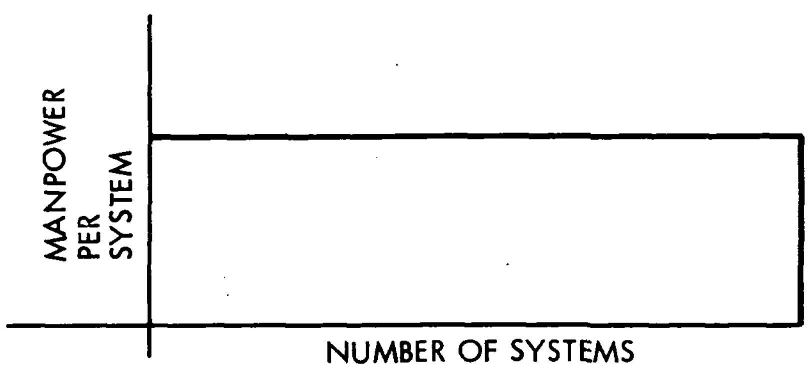


Figure 5-1. MACRIT Manpower Curve

broader policy guidelines spelled out in major support and acquisition planning documents such as MIL-STD 1388A, DOD 5000.1 and DOD 5000.2.

It is clear from this discussion that related DOD directives do not seem to provide much analytic guidance in the area of new acquisition MPT projections. Although one appraisal element was obtained via the MACRIT, this data point only represented one aspect of evaluating a much more complicated methodology encompassing task and skill analysis, personnel identification, training identification, costing, and tradeoff analysis. To obtain more data points on the manpower algorithm and evaluate the other methodology elements, it was obvious that a broader literature search was required. The following section provides the results of this broader effort.

D. CRITIQUE OF OTHER EXAMPLE MPT PROJECTION METHODS

The summary of directives provided in the previous discussion was not meant to be an exhaustive review of all related MPT DOD documentation. For the purpose of this study it sufficed to point out that the immediate and most widely used DOD acquisition and support guidelines are not fruitful sources of detailed MPT modeling techniques. A somewhat similar approach was taken with the literture search. Again, the intent was not to cover all modeling developments in MPT. For this study it was adequate to examine a sufficient number of related papers and models to obtain a solid understanding of other accepted techniques and logic employed in government and the private sector, compare shortcomings of both the DRC and other models, and ensure that a large enough array of models was examined so that all aspects of the HARDMAN methodology could be evaluated. This approach turned out to be very efficient because the literature search revealed a considerable amount of redundancy in the MPT material. In line with this finding, the following summary and analysis encompass a select group of papers that appeared to have the best data and analytic foundations as related to their respective aspect of the MPT problems. As stated earlier, the HCM covers a broad number of MPT topics. Therefore, to prevent any confusion in understanding how the various papers apply to the different topics, the following discussion is organized by each step in the methodology. The methodology steps described earlier in Section II-D are restated here in a little more depth to assist the reader in seeing the distinctions, or parallels, between the different projection techniques.

1. Summary of Papers Related to Building the HCM Historical Data Base (Step 1)

Step 1 of the HCM requires the development of a reference system that is representative of the proposed system (meets the functional requirements) and is generally composed of technically and operationally similar predecessor components. The development of the reference system is a pivotal point in the MPT analysis because a conceptual error in system configuration could result in gross MPT errors later in the analysis. The premise for conceptually building the proposed system out of predecessor components is based on the idea that technology growth is usually evolutionary rather than

revolutionary in nature. Two references were discovered, Fong's unmanned spacecraft cost model and Gordon's review of mining equipment R&D, that illustrate the "evolutionary" concept of technology development as being a reasonable and supportable assumption (13,14). Both the Fong and Gordon papers were chosen to show that the accepted concept of evolutionary technology development in fact spans several industries (i.e., the aerospace/communications industry to the mining industry).

2. Summary of Information Related to the Manpower Algorithm (Step 2)

As stated earlier in this section, one type of manpower projection algorithm is the simple Army MACRIT form (12). This form is the one employed in Step 2 of the HCM where the mission, operational, and maintenance data (extracted from the proposed and adjusted predecessor system data bases), are combined to establish the new system manpower requirements. Quade and Boucher, in their book entitled Systems Analysis and Policy Planning, employ the same basic rectangular function for projecting weapon system manpower support (15). They suggest that this algorithm is desirable largely because it provides a simple approximation of manpower (15). Another interesting insight, somewhat in conflict with the Quade and Boucher approach, is provided by Putnam in his paper dealing with projecting manpower to operate a new computer software system (16). Putnam provides essential reference backup supporting the theory that medium-to-large sized systems follow a life-cycle pattern of (1) rise in manpower, (2) peaking, and (3) gradual tailing off as the system gets older and is attrited. This cycle is termed the Norden/Raleigh cycle and closely approximates a critically damped oscillating system or a Weibull curve as shown in Figure 5-2.

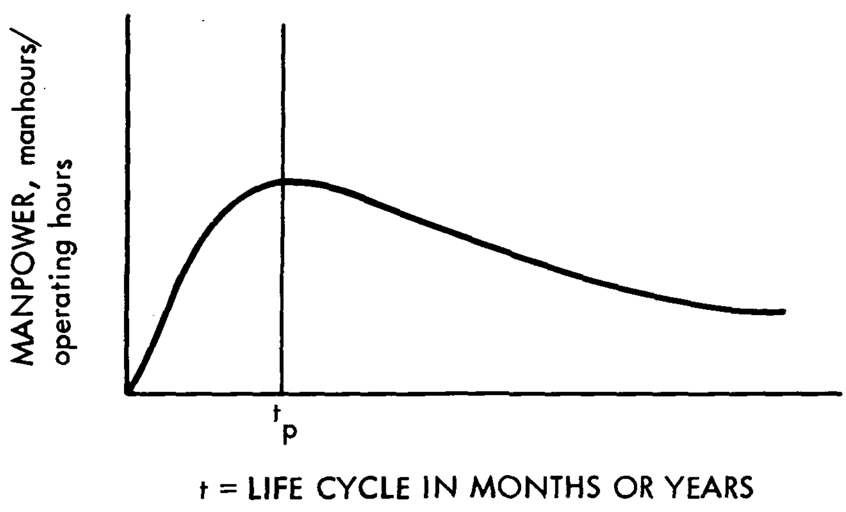


Figure 5-2. Typical Norden/Raleigh Manpower Curve

The equation, depending on the boundary conditions and how gradually the curve peaks and tapers off, is of the form:

$$MP = C_1 + C_2 t\ e^{-bt}, \text{ or, } MP = C_1 + C_2 t\ e^{-bt^2}$$

where C_1, C_2, and b are constants determined by the boundary conditions $MP = 0$ @ $t = 0$, $dMP/dt = 0$ @ $t = t_p$ (t peak), $MP = MP_{max}$ @ $t = t_p$ (t peak). The total manpower required for the life of the system is determined by integrating the above funtion(s) over the total life cycle. The important thrust of this paper is not determining the exact MP equation, but the fact that the author provides substantial backup indicating that small, short-lived projects can be modeled fairly accurately, using a rectangular MP function (16). However, large, long-lived programs (such as a large-weapon system) may require a manpower curve reflecting the more accurate buildup and tapering off of real-life systems (16). This could have major impacts on early- or later-stage, life-cycle MP requirements because the rectangular function would show a larger requirement than actually needed. Consequently, a new system being jointly phased-in at the same time or at a later stage might not have access to a needed manpower pool if the rectangular curve were used as an acquisition planning guide.

3. Summary of Papers Related to the HCM Training Resource Assessment (Step 3)

Step 3 of the HCM addresses the determination of training resources. Step 2 of the procedure provides both the number and types (skills) of people required for the proposed systems. Drawing on this information, simple programmatic matchups based on existing schools and training algorithms are employed to calculate the kinds and number of courses, instructors, training devices, and total training costs. The approach uses present curricula, devices, and associated costs where predecessor system components, similar to the proposed system, already exist. However, where new skills and training may be required the methodology provides logic algorithms (in the form of decision trees) for (1) determining whether additional training is required and (2) whether (and what kinds of) generic training devices are required. Ballpark cost estimates are then developed by using present costs of the generic devices as they exist in the other services or industry.

The PACER document, introduced earlier in Section II, is almost uniformly in consonance with the HCM (7). One effort derived from the HCM and developed by Winston, "A Preliminary Report on the Early Comparability Analysis (ECA) Methodology," examines the difficult problem of identifying, focusing in on, and training for, new hard-to-find skills (17).

Winston's effort primarily addresses the issues of force modernization versus the recruitment/retention of manpower. The object of the comparability analysis is to identify potentially high MPT drivers early in the acquisition process. Data on specific problem tasks or "high drivers" would be supported by historical, current, or projected data on MPT. Examples of data sources include (1) Army Occupational Survey Program (AOSP), (2) proponent schools (TRADOC), (3) subject matter experts, (4) Logistic Support Analysis Records (LSAR), and (5) Army Publications. The basic methodology involves the following steps:

(1) List the required tasks and MOS for the proposed system by using a similar predecessor.

(2) Establish task criteria such as % of people performing a task (PPT), task difficulty (TD), frequency of task performance (FTP), risk involved if task not performed properly (RI), task learning difficulty (TLD), training time (TT), and task decay rate (TDR).

(3) Assign subjective values of 1-4 (where 1 is "low" and 4 is "high") to each criterion, for every task identified with the proposed system.

(4) Calculate a subjective task score for each task (i.e., PPT x TD x FTP x RI x TLD x TT x TDR = Task Score).

(5) Identify high drivers.

(6) Conduct task analysis of high drivers.

(7) Establish learning/training requirements for high drivers.

(8) Determine personnel required based on test scores and available skills.

The logic algorithms employed in the HCM decision tree analysis of new skills use the same subjective task criteria as listed in Step 2 of the preceding comparability methodology.

4. Summary of Papers Related to the HCM Personnel Requirements Analysis (Step 4)

Step 4 of the HCM establishes the necessary number of people in the training pipeline to support the manpower and skill projections made in Step 2. The pipeline figure considers that personnel move in and out of various skill categories for reasons such as retirement, promotion, or changing to different skill areas. The fractional change in people moving in and out of various skill areas is based on historical data.

Several papers associated with modeling this flow process were found. Driven by a desired manpower ceiling for various skills, each model basically establishes the monthly or yearly proportional ebb and flow of people within each skill category (based on historical data) and compares the final remaining stock of people in each skill area against the desired ceiling to establish manpower shortages. Papers by Enke (18), Holz (19), Safeer (20), and Doong (21), apply specifically to the military (i.e., Army and Navy); while papers by Drummond (22), and Leeson (23), examine the problems of statewide agricultural labor shortages and police shortages, respectively. Although the terms in the equations describing the personnel flow process vary from paper to paper, the general algorithms are the same. The algorithms have the following basic form:

$$\sum_{i=1}^{n} (MP_A)_i = \sum_{i=1}^{n} P_i \, (1 - (f_{OM} - f_{IM} + f_R))_i$$

$$MP_E = \sum_{i=1}^{n} (MP_C)_i - \sum_{i=1}^{n} (MP_A)_i$$

where

$(MP_A)_i$ = Manpower available in the ith skill category after reducing the existing pool

P_i = Existing or prjected pool of people in the ith skill category

f_{OM} = Fraction of people out-migrating from skill category i

f_{IM} = Fraction of people in-migrating

f_R = Fraction of people retiring

$(MP_C)_i$ = Desired manpower ceiling for the ith skill category

MP_E = Total entrant manpower required to sustain the desired manpower ceiling

Enke suggests using probabilities in place of the fractional adjustments of the manpower pool to determine the possibility of joint events occurring (e.g., the chances of an individual leaving the Army within the interval t + n given that he has attained a certain level of training in a given skill area) (18). Enke further indicates that variables such as the state of the economy,

whether there is or is not a draft, or massive reorganizations can effect the personnel flux greatly (18). Of all the papers, the most satisfactory approach to dealing with these variables is provided by Enke. Enke points out that historical manpower flows are only useful if (1) stable socio-economic conditions have existed and will continue to exist in the near future, (2) there is enough cause-effect data to catch most reasons for reenlistment/loss, and (3) the cause-effect data are supportable by accurate statistics. However, to gain experience on how historical manpower flows are perturbed by, for example, a varying economy, he suggests using the Decisions Elements Analysis (DEA) technique (18). DEA is a survey approach whereby statistically significant sample populations of personnel enlisting, leaving, and staying are queried to establish the main drivers affecting their respective decisions. Modeled after similar successful consumer product-oriented sales DEAs, this approach provides a more accurate picture of how the population will largely behave during periods of rapid, sizeable socio-economic change. The different splits in the sample populations are then used to proportionally adjust the pools within various skill areas so that the true manpower availability more closely resembles the real world. Enke anticipates that, with time, sufficient experience with widely varying socio-economic conditions can be gathered so that personnel flow models can employ different sets of probabilities as they apply to the given (or projected) national or international situation.

By comparison, the HCM differs in the use of a starting manpower pool and desired ceiling. Both of these variables are required data inputs to all of the previous models examined. The HCM calculates the desired manpower ceiling from Step 2 of the methodology and does not depend on a historical starting pool. Instead, the HCM uses an optimization routine initiated by placing one hypothetical individual (unity) in the first open-skill area associated with a given task. The value of unity is multiplied by the historical fractional manpower flows and what initially remains is a fraction of an individual. The model then proceeds to input more individuals in the same manner, stepwise, until all the skill areas are filled in accordance with the manpower requirement. This stepwise calculation results in the total number of people in the pipeline that must be recruited and trained to compensate for the various personnel losses. The HCM does not appear to address the use of compensating factors to adjust its historical personnel loss rates according to socio-economic fluctuations.

5. Summary of Papers Related to the HCM Determination of Manpower Shortages (Step 5)

Step 5 of the HCM draws on the results of the personnel flow analysis and ultimately makes a comparison between the pipeline requirements and the present (or two-year projection) of available manpower. The resultant difference indicates manpower shortages in the various skill areas. The key difficulty with this step is finding a reasonable estimate of available manpower. If the manpower shortage is required for a near-term assessment, then the existing manpower pool is a reliable number. However, if the potential shortages must be calculated for a system deployed five to ten years

from now, then the current (or near-future) availability number may be inadequate. Several papers address the long-term manpower projection problem. All of the studies (Lindsay's future Army enlistment regression (24), Barnes' soldier 90 regression (25), and Grissmer's year 2000 manpower supply scenario (26)) were service-specific. Both the Lindsay and Barnes papers were standard linear regression models that project outyear manpower requirements. Grissmer employed a non-linear regression model that further adjusted its manpower trends up or down through the use of elasticities (i.e., weighting factors such as declining economy, unemployment, pay changes, etc.), which are projected to take effect at various time intervals and therefore distort the curve up or down as they occur. The major drawback of this techniques is that adjustments are not made to account for the lower confidence associated with outyear projections.

6. Summary of Papers Related to the HCM Tradeoff Analysis (Step 6)

The last step in the HCM is reflective in that various "what if" scenarios are developed in response to excessive costs or manpower and training shortages revealed by the results of Step 5. Many of the "what if" scenarios revolve around cost because it is a common denominator for many design decisions. In performing the various tradeoff analyses as a function of cost, the HCM usually does not extend beyond those elements directly associated with MPT (e.g., tradeoffs related to billet definition and costs, task definition, system reliability, task training, or training devices). Other life-cycle cost elements such as spares, support and test equipment, and technical documentation are not addressed.

One paper summarized in Section II was the HARDMAN Life-Cycle Cost Model (HLCCM) developed for the Navy (8). This model was specifically designed for performing a wide range of system tradeoffs. The complete program consists of several interactive life-cycle cost models that allow the designer to change input values for one or more of the life-cycle cost variables and observe the impact on the relative cost of the other support elements. The cost variables include (1) production, (2) wages, (3) spares, (4) support and test equipment, (5) maintenance, (6) technical documentation, and (7) maintenance and operator training. For example, if a new, expensive acquisition demands a large number of highly skilled maintenance people, it may be worthwhile to examine the impact of reducing the tasks and skill level by investing more money in support and test equipment to prevent the reliability from decreasing and subsequent spares from increasing. Similar to other life-cycle cost models, the HLCCM technique seems to explore more adequately the range of possible cost tradeoffs.

7. Summary of Papers Encompassing the Complete HCM

One immediate implication of the preceding discussion is that there are apparently very few modeling processes that cover the complete MPT arena. Indeed, the HCM seems to be the one process that achieves this level of coverage. However, another MPT procedure examined, which appeared to be

designed to the same level of detail, was the Air Force "Acquisition of Supportable Systems Evaluation Acquisition Technology (ASSET)" methodology (27). One of the reasons the Air Force procedure demonstrates reasonable equivalence to the overall HCM is because ASSET was originally designed by the same contractor. In its present form, ASSET represents the combined past and present design efforts of the HCM design team, Westinghouse Corporation, and the Air Force (27).

In contrast to the HCMs six major steps, ASSET has eight:

(1) Define the specific application and identify major data sources and planning documents.

(2) Construct the consolidated data base (similar to the HCM CDB).

(3) Define all operator and maintenance tasks, tools, and test or support equipment.

(4) Develop maintenance action networks.

(5) Establish other logistic support resources based on the task analysis and maintenance network.

(6) Compare the new system alternative designs against a baseline system to identify different maintenance and resource demand scenarios.

(7) Perform a life-cycle cost assessment using all of the above logistics support inputs.

(8) Develop a design option decision tree that indicates various tradeoff situations critical to logistics and human resources.

Although the Air Force technique seems to use more detailed modeling routines, it admits to having some data availability, data manipulation, and subroutine integration problems (e.g., problems with obtaining data for maintenance network probabilities or the mismatch between the ASSET personnel availability model and the equivalent information generated by the Air Force Manpower and Personnel Center) (27).

In summary, it seems that the HCM does not strongly diverge from either standard DOD MPT doctrines or other accepted MPT modeling practices. Although distinctions were made throughout the preceding discussion, the following section summarizes the major positive and negative differences more concisely.

E. COMPARISON OF DOD AND OTHER MPT GUIDELINES AGAINST HCM

The major differences between the HCM and the other various MPT modeling techniques were pointed out in the preceding paragraphs. In some cases the distinctions of other modeling practices represent improvements because they

address real-world considerations that could affect the projection accuracy. In other situations, the HCM strengths provide a stronger theoretical foundation. Table 5-1 summarizes the areas in which the strengths and weaknesses were apparent.

Table 5-1 clearly indicates that overall the HCM is fairly similar to other MPT models in its logic, use of associated MPT parameters, and input data. The major differences considered as weaknesses originated from (1) using a rectangular manpower function, (2) not making allowances in the manpower flows for the possible impacts of major socio-economic fluctuations, (3) not considering long-range manpower trends on personnel availability, and (4) not considering all operations and support variables in the tradeoff and life-cycle cost assessments. Item (1) above is important because of the potential life-cycle end point problems cited earlier during the discussion of Putnam's approach. Enke's point reiterated in item (2) cannot be overlooked because some socio-economic impacts, such as a rapid defense drop-off with change in administration, are not minor perturbations. Perturbations such as this can affect the supply of manpower for several years. Item (3) is an important consideration because the normal seven- to ten-year acquisition period far exceeds the two-year manpower planning projection used in the Army and HCM. Admittedly, the Grissmer, Lindsay, and Barnes papers referred to in Table 5-1 do not include a confidence factor in their manpower projections. However, the use of confidence intervals is standard practice and could easily be incorporated. Recommendations such as this are discussed in greater detail later in this report. The last area, item (4), was considered a weakness because all life-cycle elements must be considered to completely assess costs and design tradeoffs.

The HCM clearly exceeded some of the other studies in the areas related to building the data base and describing tasks and the personnel pipeline calculations. The data base and task area descriptions were comparatively better than the Fong or Gordon papers because these studies were not projection models. The advantage of the HCM over the series of papers related to the pipeline projection was the optimization routine. By not requiring either manpower ceiling or starting pool data inputs, the model reduced the chance of contaminating the outputs with incorrect or obsolete data.

Having identified some of the strengths and weaknesses of the HCM via the literature search, the next step was to investigate some actual applications of the methodology, drawing on the familiarization provided by the preceding comparative examination. Inferences about the overall face validity of the HCM were withheld until the audits were completed, and any obvious parallels between the literature search findings and applications analysis were identified. The final results are provided in the following paragraphs.

F. USE OF AUDITS TO EXAMINE FACE VALIDITY

The audit phase of the face-validity analysis was designed to follow the literature searches so that the inquiry might be better organized (having

Table 5-1. Comparative Overview of MPT Methodologies

Related HCM Area	Other Related Models by Author	In Comparison to HCM System Other Models are: Stronger	Reasonably Equivalent	Weaker
Step 1 Establish CDB, build predecessor ref system and develop tasks	Gordon, Fong, ASSET		X (ASSET)	X (Gordon, Fong)
Step 2 Calculate manpower requirements and skills	Quade/Boucher, Putnam, ASSET, MACRIT	X (Putnam manpower curve)	X (Quade/Boucher, ASSET, MACRIT)	
Step 3 Establish training resources	Winston, Pacer, ASSET		X	
Step 4 Determine personnel pipeline to support manpower requirements	Enke, Doong, Drummond, Leeson, Holz, Safeer, ASSET	X (Enke socio-economic considerations)	X (ASSET)	X (Enke, Doong, Drummond, Leeson, Holz, Safeer personnel flow)
Step 5 Compare personnel demands against manpower supplies	Grissmer, Lindsay Barnes, ASSET	X (Grissmer, Lindsay, Barnes long-range manpower projection	X (ASSET)	
Step 6 Conduct tradeoffs	Assessment Group, ASSET	X (Assessment Group)	X (ASSET)	

obtained some foreknowledge of the HCM process and its shortcomings). As stated earlier in this section, the three applications selected for the audits were SINCGARS, RPV, and DSWS. These three systems were chosen primarily because they represented the most recent applications of the HCM. These cases were also selected because, being at different stages in the acquisition process, they also typified different levels of study detail that is useful for examining potential data availability or credibility issues. Finally, the RPV analysis was executed by a different contractor team than the one responsible for SINCGARS and DSWS.

As an introduction, SINCGARS is a sophisticated inter-communication radio system consisting of a manpack subsystem (i.e., radio backpack) and six other radio configurations that can be mounted on different types of vehicles, i.e., trucks, tanks, etc. (28). The RPV, a small, drone-type aircraft that is remotely piloted from a mobile command center, provides surveillance information on enemy target locations (29). Last, the DSWS system is a self-propelled Howitzer linked with three other respective ammunition resupply, operations center, and maintenance vehicles (30).

Each design is fairly complex because several major components make up the complete system. Given the time and budget constraints for the total evaluation, it was decided that only select components from each system could be examined in any depth. The three following selection criteria were developed in an effort to choose key components that could surface validity problems:

(1) The component should be a major manpower driver in terms of quantity and skills.

(2) The component should require maximum exercise of the mechanics and judgmental portions of the methodology to explore validity issues such as error sources, data availability, logic, and credibility.

(3) Where possible, the component should demonstrate the least quantity and quality of source data, therefore requiring an exercise of the most judgmental portions of the methodology. These criteria would provide insight into the most likely areas where error sources, credibility, logic, or ambiguity problems could arise.

Although it was difficult to find components that simultaneously met all criteria, generally the four to six components selected for each system satisfied at least two of the guidelines. Once the studies were reviewed and the components analyzed, a detailed list was assembled that addressed all the areas where various face-validity issues could arise. The next step was to interface with the HCM designers to trace and understand exactly what was done to confirm the problem areas. This was accomplished by converting the problem list into a questionnaire, visiting the contractor's facility, and replicating in detail the analysis performed (31). The complete questionnaire is shown in Appendix C.

Two caveats pertaining to the audits should be stated at the onset. First, only the RPV and DSWS audits were actually conducted at the contractor's facility. The SINCGARS audit was performed off-site under the same guidelines as a test of the internal reliability of the methodology (32). The test of internal reliability requires that an independent group of trained individuals, given the same data inputs, attempt to replicate the results of a previous application of the methodology. Although the details of the internal validity test are provided later in Section VI, it suffices to state here that the face-validity issues surfaced during the on-site RPV and DSWS reviews also appeared in the separate SINCGARS replication.

The second caveat applies to the presentation and interpretation of the audit results. Appendix C contains approximately eighty questions related to both the three specific systems and the methodology as a whole. It should be noted that of the eighty issues examined, which covered the complete methodology, roughly 85% (or 68 of the potential issues) were adequately addressed and resolved during the audits. A summary of the remaining problem areas follows.

1. Results of the SINCGARS Audit

The major findings of the SINCGARS audit revolved around the clarity of the methodology, usability of the technique, and data management. The clarity issues primarily applied to the early Step 1 and 2 analysis done in support of the ultimate manpower and personnel projections. For example, functional requirements had to be developed as a subset of selecting predecessor components to both construct a reference system and load the historical data bank. The participants in the replication found that the detail to which the requirements could be defined had a direct relationship to the number of technically different components selected to build a reference system and, therefore, could affect the number of people needed to support the system. There were no clear guidelines provided for determining the depth to which the requirements should be developed.

Another area of contention developed over the construction of the reference system. The reference system is constructed using predecessor components that meet the functional requirements and, in turn, are similar to the proposed system(s) one desires to model. The study group discovered through the SINCGARS example the possibility that, if two or more contractor-proposed designs differed substantially, it could be very difficult to construct one reference system similar to both designs. This dilemma could result in a weaker manpower projection for one case than the other. Although the obvious solution was to develop two reference systems, the larger problem was the matter of defining how much two proposed designs could diverge before one reference system was insufficient to resemble the performance of both.

One area closely associated with the manpower projection is the process of evaluating design differences between the predecessor and proposed components and defining the fractional improvements in maintainability and reliability performance. The first major difference occurred over the selection of the so-called "perturbation values," which are the ratios used to adjust reference data to better represent the performance of the proposed

component. The study participants found that, because there were not established guidelines for selecting perturbation values, their perceptions of certain design improvements varied widely. This variance could have a major affect on the manpower outcomes.

The study group suffered similar confusion over guidelines associated with the selection of indirect productivity and induced failure values. Although distinct values were provided for SINCGARS, the group recognized that the MACRIT, which is the source of these values, provides a range of selection. Again, not being given guidelines in the methodology on how to select either a high or low factor over a fairly wide range of potential values, the study participants felt that the final manpower projection could be affected considerably.

The last, most important, difference was associated with a misunderstanding of how the perturbation values were actually used in the manpower calculation. It was discovered that the HCM presently uses perturbation values only to fill data gaps in the proposed designs. Occasionally, HCM analysts find that contractors do not provide performance data on all the components in the proposed design (such as SINCGARS). While constructing the reference system out of similar predecessor components, the analysts will select the predecessor component equivalent to the missing component in the proposed design and "perturb" the historical performance data in order to complete the data set for the new design. However, in the final manpower and personnel projections the total reference system predecessor data are not upgraded (using perturbation values) to allow the complete new design to be modeled based on proven historical information. This procedure represented a major logic problem to the control group because one of the primary reasons for modeling new system manpower requirements is to prevent contractors from being overly optimistic about the impacts of new technology improvements. By not upgrading the old technology to a roughly equivalent proposed configuration and establishing a revised historical data base against which to equally compare proposed designs, the methodology cannot test the integrity of contractors. Without making an equivalent technology-based comparison, the same trivial outcome will always result; the new technology will appear to perform better than old technology (i.e., the new technology will require either fewer or lower-quality skilled people).

One area of contention that arose over the personnel assessment portion of Step 2 in the methodology was the matching process between tasks and skills. The participants found that the cookbook approach outlined in the methodology was not completely accurate. This definitive approach is normally followed up with the analysts actually contacting various Army training schools to confirm, or update, the task and skill matchups. Because this caveat was not passed on to the participants, there was general disagreement between the skills selected by the original methodology designers and the skills selected by the control group.

The last two areas pertaining to the usability and data issues were more related to the methodology as a whole. The analysts discovered that, although they jointly had backgrounds in mathematics, engineering, and personnel, they still lacked the range of training and experience necessary to completely comprehend the pitfalls and nuances of the methodology. The overall conclusion was that the methodology could not be properly exercised unless a

well-seasoned, multidisciplinary team having joint military, engineering, data management, and personnel backgrounds was employed. The last problem area, data management, was not necessarily viewed by the study participants as a shortcoming of the methodology. The observation was made that the complex nature of the MPT issues alone caused the methodology to contain many places where errors could be introduced due to (1) the prodigious quantity of data required and (2) the large amount of data manipulation required.

2. Results of the RPV Audit

The RPV audit surfaced several potential validity problems involving elements of the early data-sorting process, manpower and training projections, as well as the later tradeoff analyses. The most important finding related to the initial data base step was the lack of a clear decision process for selecting and using different sources of performance data (e.g., reliability and maintenance data). For example, it was stated earlier in this section that the methodology normally requires historical data to be used for modeling new system performance. However, in the RPV case, most of the components had already been prototyped so that actual reliability and maintenance test data existed. Nevertheless, the decision was made to use only some of the contractor test data. The remaining maintenance data were discarded and relaced by comparable information listed in the design specifications that were part of the original proposal. The reason cited for this action was that experience dictated the contractor data was not reasonable. Another example of non-distinct direction for data selection pertained to modeling component performance on the small RPV using comparable components on full-sized aircraft. The reason the contractor opted to use this information was because the Army, having no history of using drones, did not have comparable predecessor data. Closely associated with this decision was the fact that the original designers did not differentiate between the different performance and environmental envelopes of the aircraft. These differences could affect the stress levels and resultant wearout rates experienced by the RPV components. The confusion over the selection of data sources, although somewhat linked to concerns about accuracy, more specifically revolved around (1) identifying the various data sources and ranking them as a function of quality and (2) determining when to use one source in preference to another.

In the manpower and personnel step following Step 1, the analysts found the same problems with selecting perturbation and induced failure values that were discovered with SINCGARS. Similarly, the step of matching skills with tasks lacked a clear audit trail as to how the final skills were selected. This particular audit problem was derived from the fact that the Army did not list skills for operating and maintaining drone-type aircraft. Therefore, the HCM analysts had to search outside the normal cookbook procedure to define the new skill areas and obtain associated wage and training information. Regarding the final manpower projection made in Step 2 of the methodology, the step function deployment assumption discussed earlier in the literature search was confirmed. As indicated before, this assumption is considered a problem because of the potential personnel allocation conflicts imposed by other acquisitions under concurrent development.

Step 3 of the methodology, the training resource assessment, surfaced some interesting problems with respect to RPV. The analysts discovered that, although the methodology provides for a very detailed instructor, training resource and cost asessment, it has only been marginally exercised because of lack of data. Critical training considerations such as the identification of safety related tasks or task difficulty were not highlighted. Additionally, the audit team found that the methodology did not differentiate between the instructor contact hours required for critical versus non-critical tasks. The analysts felt that this was particularly important because RPV appeared to be a new technology area not previously employed by the Army.

An in-depth investigation of the personnel shortage projection in Step 5 of the RPV study was very revealing. The investigators found that, although the modeling algorithm for calculating shortages was sound, the weakness pertaining to the use of the short-term manpower availability projection cited in the previous literature summary was verified.

In the final step of the RPV study, tradeoff analysis and conclusions, the analysts experienced considerable confusion over the criteria for (1) performing certain tradeoffs and (2) identifying the one MPT projection that represented the best estimate of the real-world performance of the proposed system. For example, in the training assessment several cases were found where the design dictated the use of low pay grades in certain task areas. However, when the training courses were structured based on predecessor systems, it was found that rather high skills were actually required for the same tasks. Although the study indicated that this mismatch was a major conflict, the training and cost implications were never pursued in the tradeoff analysis. This ambiguity about the relative importance of various tradeoffs did not give the analysts confidence that (1) all possible tradeoffs had been considered; (2) important tradeoffs, such as the above example, had not been overlooked; and (3) the tradeoffs finally pursued represented the pivotal issues. The largest source of ambiguity in the RPV study revolved around the presentation of the final MPT and cost projections. The present summary format for the projections displays both the reference and proposed results together. However, where wide variations between the projections occurred (such as SINCGARS) or when several proposed systems were presented (such as RPV), it was not clear which set of results represented the most accurate approximation and MPT planning guide. The audit team found that the source of the confusion originated from not having an indication of the relative credibility of the data inputs and outcomes.

One final interesting aspect noted by the analysts applied specifically to RPV but not to SINCGARS. The observation was made that because the RPV study was completed roughly one year before this evaluation, the members of the original HCM study team did experience memory decay with respect to their decisions and judgments about the use of certain data sources and the ultimate selection of one of the proposed system designs as the best planning figure. This last finding was important because it demonstrated that, even with a seasoned corporate bank of knowledge, the judgment areas in the methodology must be better structured to allow a firmer audit trail.

3. Results of the DSWS Audit

The findings of the DSWS audit were quite similar to both SINCGARS and RPV. The main reasons for the similarities were (1) the DSWS reference system was compared against several, widely varying proposed designs; (2) a significant amount of data sorting and selection was required; and (3) the original DSWS analysis was also completed well before the methodology validity evaluation. The chief problems encountered by the investigators related to item (1) above were those associated with defining the proper level of detail for the functional requirements and building one reference system to model four widely varying contractor concepts. Like the SINCGARS audit, it was felt that the lack of sufficient detail on functional requirements and singular reference system constraints could cause major variance and errors in the operational and maintenance manpower support projections. Item (2) above was extremely important because of the confusion generated in trying to sort and categorize generic component repair times by specific task, establish the credibility of the various data sources, and understand which data sources had priority over others. The DSWS data question was analogous to the earlier defined RPV data problem. Item (3) addresses the audit trail decay dilemma similarly revealed with the RPV study.

As was the case with both the SINCGARS an RPV investigations, the analysts did not clearly see the selection criteria for the DSWS perturbation values, indirect productivity factors, and final choice of skills. Finally, the investigators were confused by the way the data were presented for the final design option selected as the MPT planning guide. Similar to RPV and SINCGARS, the study team felt that the best option should have been respectively chosen as a function of (1) the relative quality of the various data inputs and (2) a comparison against a reference system that had been perturbed so that the historical and proposed designs were compared on an equal technological basis.

G. VALIDITY IMPLICATIONS

The preceding discussion highlighted many strengths and weaknesses of the HCM. The overriding strengths were:

(1) The methodology conformed well with DOD and Army doctrines.

(2) The technique basically resembled other known, accepted MPT modeling techniques in its logic, use of MPT variables, and input data.

(3) The methodology was reasonably well supported by its data sources.

(4) The HCM surpassed most other models in its completeness and integration of various MPT modeling techniques.

(5) The methodology provided a better modeling foundation in some areas than other simulations (e.g., manpower pipeline projections).

(6) The HCM stood up reasonably well under an extensive audit (i.e., 85 percent of the test issues were adequately answered).

However, the audits confirmed some problem areas outlined in the literature search. During the process of replicating the three case studies the remaining 15 percent of the test issues revealed that (1) the HCM conformed with the MACRIT in its use of a rectangular manpower curve with no consideration of the Norden-Raleigh reduced end point demands; (2) the HCM did not address Enke's potential impacts of major socio-economic fluctuations on personnel flows in and out of various skills, and the Army as a whole; (3) the technique did not project manpower availability and shortages at the actual projected deployment time of the new system; (4) the HCM incorporated, but did not exercise, a technique similar to Winston's subjective critical task assessment; and (5) the HCM MPT system examined only a small number of life-cycle cost tradeoffs (e.g., wages, reliability changes, task redefinition, training programs and devices). Additionally, in the data base construction phase, early in Step 1 of the methodology, there was a wide variance in (1) the types and sources of data selected, (2) the reliability and maturity of the data, and (3) the methods used in screening and manipulating the data to conform to the methodology or to fill data gaps. This wide variance caused a major problem in establishing the credibility of both the analysis and final projections. It was also discovered in Step 1 that, by not reaching the proper level of indenture for the functional requirements, key tasks and subsequent manpower support could be left out. Another major finding associated with the reference system portion of Step 1 was particularly apparent in the SINCGARS and DSWS audits. It was discovered that where several widely varying new designs were being considered, the use of a single-reference system could be an inadequate performance comparator for some of the proposed concepts. Also linked to the reference system procedure was the problem of not adjusting the predecessor historical data as a function of the proposed design improvements. This was a pivotal discovery because the contractor-projected manpower and costs could not be assessed on an equal basis with what would be considered a reasonably equivalent extension of existing technology.

The manpower and personnel projection phase of the audits uniformly revealed that a better logic structure was required for selecting perturbation values, indirect productivity factors, and induced failure rates. It was found that arbitrary selection of these different values would affect the ultimate manpower projection, particularly where small variations in manpower support (such as at the field level) could cause critical shortages. In the personnel selection step it was found that HCM's actual skill matching process extended beyond the scope of the stated methodology. The resultant skill mismatch and cost impacts were felt to be potentially sizeable.

In the tradeoff and conclusion portion of the methodology, Step 6, the audits revealed a definite need for (1) a clear structure for selecting tradeoffs and (2) a subjective weighting mechanism of the various data and judgmental elements of the methodology to establish the credibility of both the final design selected and the accuracy of the analysis as a whole.

Overall, the findings of the audits suggested that the structure of the judgmental portions of the methodology still needed to be improved to offset the observed audit trail decay. Furthermore, the sophistication of both the MPT problem and the HCM design did not make the process amenable to use by lay people. Although the preceding discussion indicates the various sources of

potential errors, logic problems, ambiguities, or credibility issues, Table 5-2 more concisely illustrates the link between these findings and complete array of respective face-validity elements defined earlier in this section.

The face-validity analysis provided an indication of the strengths and weaknesses of the HCM, as well as a first-cut, general examination of the integrity of the technique. The next step was to investigate and tailor validity tests to examine more specifically the accuracy and reliability of both the overall methodology and its projections. The validity tests selected for the reliability portion of the study, selected to conform with the project time and budget constraints discussed in Section III-E, are discussed in detail in Section VI along with the results of the complete reliability analysis.

Table 5-2. Summary of Audit Results in Terms of Face-Validity Elements

Problem Areas as Function of Methodology Steps	Face Validity Elements					
	Possible Incorrect Logic	Technique Not Easily Used	Possible Error Source	Data Not Available	Process or Results Ambiguous	Potential Credibility Problem
<u>Step 1</u>						
Lack of structure for selecting and adjusting source data		X	X		X	X
Lack of structure for determining level of indenture of functional requirements		X	X		X	
Construction of one reference system to model several widely varying proposed designs	X		X			X
Non-adjustment of historical predecessor data to allow equal technology comparison between reference and proposed systems	X		X			X
<u>Step 2</u>						
Use of rectangular manpower curve that is insensitive to lower end-point manpower demands		X	X		X	

Table 5-2. (Cont'd.)

Problem Areas as Function of Methodology Steps	Face Validity Elements					
	Possible Incorrect Logic	Technique Not Easily Used	Possible Error Source	Data Not Available	Process or Results Ambiguous	Potential Credibility Problem
Non-structured selection process for perturbation, indirect productivity, and induced failure values		X	X		X	
Incomplete description of skill matching and selection processes		X	X			
<u>Step 3</u>						
Non-differentiation between critical and non-critical tasks			X	X		
<u>Step 4</u>						
No consideration of impacts of socio-economic fluctuations on manpower availability			X			
<u>Step 5</u>						
Lack of procedure for projecting manpower shortages based on actual system deployment data	X		X			X

Table 5-2. (Cont'd.)

Problem Areas as Function of Methodology Steps	Face Validity Elements					
	Possible Incorrect Logic	Technique Not Easily Used	Possible Error Source	Data Not Available	Process or Results Ambiguous	Potential Credibility Problem
<u>Step 6</u>						
Incomplete life-cycle cost analysis			X			X
Unclear criteria for conducting tradeoffs			X		X	
Lack of indicators for data quality and analysis credibility					X	X
<u>Overall</u>						
Slight observed decay of corporate audit trail					X	X
Requirement to have a well seasoned, multi-disciplinary team conduct the methodology		X				

SECTION VI

RELIABILITY ANALYSIS

A. OVERVIEW

As explained in Section III, the reliability, or accuracy, of the HCM was explored via three avenues. The reliability of the HARDMAN methodology was assessed by examining internal reliability, to a limited extent an examination of the experience of individuals who have already applied the HCM (or other similar methodologies) to real-life applications, and event series validity.

For the internal reliability test, it was decided to use one of the Army test cases (i.e., SINCGARS). A controlled experiment was designed to establish whether a group of individuals, trained to use the methodology, could both replicate the original answers and also demonstrate a low degree of variance in their answers. A group of seven individuals (four civilians and three career Army soldiers) of varying backgrounds, were selected for the experiment. Given the small sample size (primarily due to restrictions in available people, time, and budget) it was decided to dispense with detailed statistical comparisons and simply establish general conclusions about the repeatability and consistency of the results. The replication was also used to develop a list of critical factors that have major impacts on MPT projections. For purposes of consolidating the internal reliability findings and to find ways to improve future versions of the HARDMAN methodology, each participant went through a formal debriefing. Furthermore, a discrepancies resolution conference, attended by the study group, ARI, and HCM designers, was held following the completion of the replication.

Another important step in the reliability examination was a qualitative accuracy check of past Air Force and Navy experience with the same (or reasonably close) methodology. This was done by personally contacting pertinent project personnel.

The last step in the reliability examination was a manpower sensitivity analysis. Sensitivity analysis is a useful tool for testing how well a technique like the HCM must conform with the real world. This type of test is often referred to as an "event series validity test" because it ultimately provides an acceptable accuracy or reliability envelope for the outcomes of a modeling process. If the envelope is rather large, then a quick-and-dirty approximation is acceptable. As the envelope shrinks, greater emphasis must be placed on improving the quality and accuracy of each data input and algorithm. In this evaluation, the sensitivity (or event series) analysis was done last to assist in formulating and prioritizing the closing recommendations for improving potential problem areas in the methodology. To obtain an indication of the required accuracy of the HCM, a simple top-down cost sensitivity analysis was designed to establish the allowable variance in the manpower projections which would still provide accurate MPT estimates. The estimates of the allowable variance in the manpower projections were performed for one sample acquisition using an actual Army system. Each element of the reliability analysis is described in greater detail in the next subsection.

B. APPROACH

1. Internal Reliability

The replication effort for evaluating internal reliability involved the application of the first two steps of the HARDMAN methodology to the Army's Single Channel Ground Airborne Radio System (SINCGARS). These two steps were:

(1) Establishing a consolidated data base.

(2) Determining manpower requirements.

The remaining four steps were not included for several reasons. First, preliminary review of the HCM process suggested that there were a substantial number of judgments, having considerable influence on the manpower estimates, in the first two steps. Second, at the time the replication was performed, HCM designers had only completed their analysis on the first two sections of the methodology. Third, other duty commitments mandated that the experiment be simplified so that the Army participants could finish the replication within a maximum time frame of three weeks. The SINCGARS components included in the replication were as follows:

(1) Receiver/Transmitter Unit (R/T).

(2) Electronic Counter-Countermeasures Unit (ECCM).

(3) ECCM fill device.

(4) Securable Remote Control Unit (SRCU).

These components were confirmed as offering the greatest number of judgment exercises.

A group of seven individuals with varying technical backgrounds (i.e., math, engineering, psychology) and experience (JPL, Soldier Support Center, Army Research Institute) were selected for the testing. This group attended the HCM training course, which was held at the HCM designer's facility in Boston, Massachusetts, during February 1983. The goal of the course was to familiarize the participants with the key analytical and judgment areas in the first two steps of HARDMAN. During the training sessions, the methodology was applied to an example subsystem of the Army's Multiple Launch Rocket System.

For the SINCGARS replication effort the two steps were divided into eight different data packages. Each package required the determination of key judgment and calculational outputs and was preceded by (1) a problem statement related to the judgments that were required, (2) a list of the enclosed data items to facilitate making the judgments and necessary calculations, and (3) a brief statement about how to use the data. The problem statements and descriptions of the data packages are given in Table 6-1.

In general, the participants were to proceed independently and sequentially through the eight data packages until the four components of SINCGARS identified for the replication effort were evaluated. Three weeks

Table 6-1. Data Package Problem Statements and Descriptions

Problem Statement	Date Package Description
Develop system functional requirements	Descriptive data for proposed system and one worksheet for each subcomponent
Construct reference system	Candidate list of predecssor systems and description of contractor proposed systems
Define tasks	List showing range of generic classes of tasks and contractor task definitions for proposed systems
Reliability and maintenance determinations for inherent versus induced component failures and assignment of task echelons	Task time data, component failure data, induced failure data, equipment breakdown structures, predecessor task echelon assignments - one worksheet for each component
Determine design differences (design difference analysis, impact of design differences, derivation and application of perturbation values (PV) to appropriate tasks)	Data extracted from 1, 2, and 4, above, summaries of contractor correspondence with component contractors and one worksheet for each component
Select and assign MOS	List of candidate MOS from which to choose appropriate specialties for each task
System/component usage rates	Select data extracted from the operational and organizational plan
Determine workload and manpower requirements	Data extracted from 1-7, above, available manhours - one worksheet for summary of results

were allowed to complete the SINCGARS replication. The study group was permitted to ask the HCM designers questions of clarification only by way of a mediator. It was originally planned to provide feedback to the students at selected audit points in the analysis for the first two SINCGARS components (to allow mid-course corrections) and to provide no feedback for the last two components to get a feel for what the end-point variance might actually be, given no student coaching. In actuality, because of the huge quantity of data involved and the relatively short time frame, feedback was given to the students after each data package completion for all four components.

The internal reliability was primarily assessed by reviewing the study group's answers to the data packages and by comparing them to the baseline HCM designer answers. Besides a reliability measure, convergence of answers would suggest that the judgment activities could be done by any individual with appropriate training whereas divergence would indicate inadequacies with the methodology, student background or experience, or HCM training (or possible combinations of these problems). Another major step in the analysis was a structured telephone debriefing of each participant to identify subjectively major problem areas in the replication or methodology.

The analysis of each data package within the reliability effort involved either a subjective review of the participants' responses or a numerical evaluation of the key answers as compared to those of the HCM design team. To protect the confidential nature of the replication, the participants were referred to by number only (from 1 to 6). After the replication was completed, each participant was debriefed to define individual problem areas with the packages and to get feedback for possible future improvements in the methodology. The debriefing specifically addressed relevance to present assignments, difficult portions of the replication, discrepancies between the HCM designer and study group answers, and the adequacy of the HARDMAN training course (see Appendix D for a sample debriefing questionnaire).

The last major component of the internal reliability analysis was a discrepancies resolution conference, which was held during August 1982 at the Soldier Support Center at Ft. Benjamin Harrison, Indiana. This conference was attended by the study group, representatives of JPL, the Army Research Institute, and the HCM designers. The purpose of the meeting was to provide a structured means of resolving differences and misunderstandings resulting from the replication. This conference was a two-day activity in which each of the eight data packages was examined and discussed in detail.

2. Qualitative Accuracy Check

The qualitative accuracy check was conducted by using participants in existing military projects that have used some form of similar manpower estimating methodology. The projects covered included the Advanced Lightweight Torpedo (ALWT), the DDGX destroyer, the VTXTX flight trainer, and the SUBACTS submarine combat system. The pertinent project personnel were asked their opinions on the validity of the HARDMAN methodology as compared to other methodologies, as well as real-life data.

3. Manpower Sensitivity Analysis (Event-Series Validity)

The objective of the sensitivity effort was to roughly approximate the permissible variation in the manning variable. To accomplish this objective, four tasks were undertaken. The first was to develop a data set of actual costs for the SINCGARS system. The second was to develop approximate manning data for SINCGARS. The third task was to determine broad, acceptable limits of error on total life-cycle cost estimates according to authorities engaged in the budget and acquisition review process. The final, and largest, task was to determine the extent of error allowable in manpower and training cost estimates, given that other cost elements cannot exceed the limits of their allowable ranges.

Within Task 1, data were collected reflecting typical costs of various elements of life-cycle cost. The major components of total cost were identified in an attempt to determine approximate ranges. It was decided that if possible, the more difficult-to-identify elements of life-cycle cost would be ignored if their relative sizes were small. In Task 2, actual training, manpower, and training estimates associated with SINCGARS were determined. In Task 3, a variety of participants in the acquisition process were interviewed to determine what guidelines they use for the range of acceptability of errors. The groups contacted included OSD or CAIG, who are involved in the review of DOD acquisitions. The results of these interviews were resolved into perceived admissible limits of error on total life-cycle cost and each of its components. In Task 4 the allowable variation in manpower cost in the presence of other acceptable errors in the estimate was determined. This study used an already developed life-cycle cost and level-of-repair model to study the interrelationships between projection errors for several quantities (8). The central idea was to determine how large or small the permissable error in manning estimates could be as a result of these relationships.

The first step in Task 4 was to identify all the variables that influenced manning and manning estimates. Next, other readiness-critical quantities estimated in the model that depended on the same inputs were identified. There are five major sources of variance in manning requirements. These are the equipment operating program, the deployment plan, reliability, maintainability, and manpower characteristics. Together they determine actual manning, and estimates of the variables that describe these areas subsequently impact the accuracy of manning estimates.

The operating program describes the number of hours during which the force is expected to operate the equipment. This might be twenty hours a week, one or one hundred sixty-eight. During the life of the system, these numbers will aggregate to a total usage that will have a fundamental effect on total life-cycle cost. But for any given period within the life cycle, the rate or pace of operations will help determine the demand rate for repairs.

The deployment plan simply tells how many units will be purchased and deployed in the field. By extrapolation, the equipment operating hours are determined, both over the entire life cycle and per unit of time. The deployment plan also usually explains how usage rates are distributed among operating units. This is important because of the effect of geographic separation on various costs (i.e., pipeline delay times, number of maintenance facilities, etc.). For example, a division may generate the requirement for only one half a manyear of labor per year to repair a type of equipment. While most labor costs would therefore be accounted for at half cost, training would not, because a whole man must be trained for each division.

The reliability of an equipment expresses the rate at which failures occur as a result of usage. In company with the operating program and deployment plan which determine the usage rate, the reliability measure (either mean time between failures (MTBF) or failure rate) gives the demand rate for repair services. These three areas jointly determine how many failures must be repaired per unit of time.

The maintainability of an equipment is expressed by the average time required to repair it. In most systems this can be divided into two repair times. The first is system restoration time estimated as the mean time to remove and replace a faulty component (MTRR). The second is the mean time to repair the faulty component after the system has been restored (MTTR). The system support policy is usually developed by analyzing the relative costs of undertaking these two repair actions in different ways and at different places. An item is discarded if the cost of repairing it, including all the training, equipment and manpower consumed, exceeds the cost of buying a replacement. When the converse is true, then the difference between repair on the spot versus repair at a depot must be computed. At the organizational level, the system is generally repaired through fault isolation and replacement of the failed module. The failed module may then either be repaired or discarded.

The last major determinants of manning are characteristics of the manpower itself. These will include quality (skills) and a version of quantity. The quality of manpower will have an effect on repair times. Generally speaking, these skills are set at the lowest level capable of being trained through the service schools and cannot be dealt with in the estimation process. Quantity is related to the amount of work available from a single individual in a period of time. Typical times are 40 to 60 hours a week. Depending on the circumstances, these limits may also be exceeded.

It should be noted that other LCC variables such as special support equipment, tooling, etc., can effect manpower and, therefore, represent additional manning drivers. However, for the purposes of this top-level sensitivity study, variables such as these were not major manpower determinants and were therefore not considered.

SINCGARS was selected as the system to illustrate the error bound interrelationships because it had been studied previously in the HARDMAN project and because it represented a small (therefore, easy to model) but important electronics system. The cost model used to perform the analysis is an adaptation of the LCC model summarized earlier in Section V developed by the Navy HARDMAN Office (8). The bulk of the modifications made to the LCC model were aimed at converting the computer software to a fast turnaround system suitable for extensive sensitivity analysis. In addition, certain values were added to the printed output, along with the ability to impose predetermined support policies at the line replaceable unit (organizational) level.

The model is a level of repair and life-cycle cost model that was developed especially to be sensitive to the relationships that drive manpower costs. It is roughly based on the MIL STD 1390 group of level of repair models although the errors implicit in those models have been corrected, and several innovations have been added to the computational procedures (8).

An example baseline cost estimate is shown in Table 6-2. The SINCGARS life-cycle cost estimate is $784 million, excluding batteries. The batteries were left out of the cost estimation process because they consumed a great deal of computational time and added little to the analysis. Manning (in manyears) is summarized in the lower right corner of the table. Real manning

Table 6-2. Baseline Life-cycle Cost Sensitivity Analysis Run

Cost Elements, M$		System Rates	
Life-Cycle Cost	783846.0	Number of LRA Types	17
System-Unit Cost	11.1	Number of LRAs	17
INITIAL COSTS:		Confidence Against Stockout	0.999
Production	312296.0		
Maintenance Training	1104.2		
Operator Training	70280.0	System MTBF	472.3
Misc. Manpower	0.0	System MTTR	3.0
Spares	2512.2		
S+TE	67048.6		
Technical Documentation	55.2		
TOTAL	453296.0	SUPPORT POLICY SUMMARIES:	
		LRAs coded COD	0
OPERATION AND SUPPORT COSTS:		LRAs coded MOD	9
Maintenance Wage	27457.5	LRAs coded local repair	4
Operator + Office Wage	31019.4	LRAs coded discard	4
Maintenance Training	3390.6		
Operator Training	215920.0		
Misc. Manpower	0.0	TRAINING BILLETS BY TYPE:	
Spares	9577.7	Equipment Operators	28112
Repair	1962.7	Org. and Int. Maint.	420
Transportation	17.6	Depot Technicians	6
S+TE	41198.5		
Technical Documentation	5.5	REAL MANNING REQUIREMENTS:	
		Org. and Int. Maint.	205.12
TOTAL	330550.0	Depot Maintenance	4.27
		OPERATORS	7028.00

requirements indicate the total number of manyears of labor, for all skills, actually consumed by SINCGARS each year. These manyears are not necessarily consumed in full manyear increments because labor requirements are distributed over a number of geographical units (28 divisions, in this example). The effect of geographical distribution is to expand the real manning requirement to a larger number of billets required for training purposes. Because it is not possible to train portions of people or to give people part of the training required, training billets are constrained to be full integers; and one must be developed for every individual who is required to work on the system, no matter how little time is spent with it.

The most extensive manpower requirement is for operators. This shows up in the consumption of real manning requirements as well as in the establishment of training billets. A glance at the list of costs also shows that, with the exception of production cost, operator training and billet costs constitute the largest elements of life-cycle cost for the SINCGARS example. However, while operator costs appear to be important in the estimation of total cost, they are unimportant in this study because they are unresponsive to changes in most of the input variables that influence maintenance manning. It is understood that the relationship between operators and maintainers may vary from system to system.

The SINCGARS manpack version was modeled as a collection of 17 (18, including the battery) line-replaceable units. In fact, the SINCGARS program office basically views the equipment as consisting of four modules (R/T, handset, whip antenna, battery) among which the R/T breaks down into LRUs. Because the other three modules have only one piece and are discard items anyway, the equipment's structure was simplified to accommodate the computational problem, treating modules as LRUs along with the LRUs that make up the R/T.

The model is driven by inputs that describe the support and deployment environment, the system design, and the particulars of component design. The data used in this exercise were selected as representative acquisition values and are reported in Appendix E, along with the component cost sheets.

The model operates by estimating life-cycle cost for each component in four different support postures. Normally, the least costly of these is determined, and the output data associated with it are forwarded to the system cost estimate. In the current example, support policies had already been determined, and these were used to override the cost-minimizing routine of the program.

At the same time that costs are <u>aggregated</u> by the system model, certain variables of concern are <u>aggregated</u> as well. These include reliability, maintainability, and system-configuration summary data, as well as an accounting of the support postures selected for the different LRUs. While it is understood that skill tradeoffs cannot be examined using aggregate costs, the use of total costs for a top-level sensitivity study such as this was acceptable. Finally, the cost tableau is broken down into investment of initial cost and operating and support costs. Initial costs include both production and logistic investments. Drawing on both the Table 6-2 baseline costs and perceived acceptable LCC error bounds, the above cost model was iterated until the relationship between manning and the previously identified five major LCC variables could be clearly plotted.

C. SINCGARS REPLICATION RESULTS

1. Work Package 1 - Develop System Functional Requirements

The functional requirements data package consisted of three subtasks:

(1) Identification of functions and performance standards of SINCGARS Manpack system.

(2) Organization of the functions and standards into a functional hierarchy.

(3) Allocation of the functions to equipment and people.

The HCM designers' answer sheet was a matrix that matched subsystem elements and performance standards to functions (see Table 6-3 for a sample answer sheet).

There were no numerical answers to evaluate in this package. Part of the study group adjusted the answer format. Additionally, differing semantics among the participants complicated the analysis. That is, a "participant" could mean the HCM designers but use different wording. Neither of these last two factors necessarily made an individual's answers incorrect. In order to evaluate the answers, it was decided to determine whether or not the participants included the major functional requirements in their answers. As shown in Table 6-4, none of the respondents had the function "Operate SINCGARS." However, the remainder of the answers indicated that the study group understood that this was included. All respondents had "Communicate" and four (2,3,4,6) had "Accommodate Mobility," but only two had "Command Control." It should be noted that an "X" indicates matching answers between the HCM contractor and respondents.

In terms of format, one participant had three extra element columns (adaptor, shorting block, COMSEC), while another individual never used the backpack column. Two individuals itemized tasks rather than functions. Three individuals missed at least some performance standards. On the other side of the spectrum, five of the study group included extra items such as "pass through retransmission" and "monitor net," which the original HCM designers did not have. In this sense, the study group's answers were more complete.

In the debriefing it was found that two of the group were confused as to the HCM usage of "end item." The study group as a whole was unsure about much detail to give in its answers. Regardless of some of the above confusion, the major functional areas were basically understood and covered by the participants even though they were limited by an open-ended answer format.

2. Work Package 2 - Reference System Selection

The objective in this package was to select the reference system based on the following given information:

(1) Functional requirements.

(2) Reference system candidate equipment.

(3) Proposed system design data.

The analysis of this package was based on the ability of the replicants to specify the four major system components: R/T, ECCM, ECCM Fill, and SRCU. Given the correct selection of the radio/transmitter (AN/ARC-114), the remainder of the components generally followed. As it turned out, all

Table 6-3. Functional Requirements Answer Sheet

SYSTEM SINCGARS

FUNCTION TO SYSTEM ELEMENT ASSIGNMENT MATRIX

FUNCTION	ELEMENT: R/T	ECCM UNIT	ECCM FILL	SRCU	BACK PACK	PEOPLE	PERFORMANCE STANDARDS
1.2 COMMAND CONTROL	X		X	X		X	2.0 VOLUME OF INFO: INCREASE
							3.0 SURVIVABILITY
1.2.1 CONTROL COMMUNICATIONS LOCALLY	X					X	2.4 # OF CHANNELS: INCREASE
							2.5 # OF PRESET CHANNELS: INCREASE
							3.1 # OF POWER SETTINGS
							3.2 KHZ OF FREQUENCY OFFSET: INCREASE
1.2.2 CONTROL COMMUNICATIONS REMOTELY				X		X	2.1 # OF RADIOS CONTROLLED: INCREASE
							2.4 # OF CHANNELS: INCREASE
							2.5 # OF PRESENT CHANNELS: INCREASE
							3.1 # OF POWER SETTINGS: INCREASE
							3.2 KHZ OF FREQUENCY OFFSET: INCREASE
1.2.3 ESTABLISH RADIO NET	X		X			X	2.1 # OF RADIOS: INCREASE
							2.4 # OF CHANNELS: INCREASE
							2.5 # OF PRESET CHANNELS: INCREASE
1.2.4 CONTROL RADIO NET	X			X		X	
1.3 ACCOMMODATE MOBILITY					X	X	3.0 SURVIVABILITY:
							4.0 AVAILABILITY:
1.3.1 ACCOMMODATE MOVEMENT BY MAN					X	X	3.4 ANTENA VISIBILITY:
							3.5 WEIGHT:
							4.5 BATTERY LIFE:

Table 6-4. Work Package 1 - Respondent vs. Dynamics Research Corporation Results

Major Functional Requirements	DRC	Respondents 1	2	3	4	5	6	Total Number Correct
Operate SINCGARS	X	Not specified but inferred						
Communicate	X	X	X	X	X	X	X	6/6
Command Control	X					X	X	2/6
Accommodate Mobility	X		X	X	X		X	4/6

participants had doubts concerning the HCM designers' answer. Several felt that their selections were better suited as the baseline system. In the discrepancy review the HCM designers explained that the 114 had the most available data. This was obvious from a data source matrix that was not given to the study group. This mismatch also suggested that the group did not understand the relationship between comparable component selection and data availability for that component.

This package was among the easiest to grade of all the packages (see Table 6-5 for the answer comparison). Three individuals (3,5,6) had the correct R/T. Two of these three had the remaining major components correct as well. As in Package 1, the level of indenture was again a concern. All participants were missing at least some detail. Minor subsystems such as fill cable and battery were missed by everyone except Participant 1. Two individuals had some detail (i.e., programmer gun, antenna) that was not included by the HCM contractor. Aside from the doubts on the HCM designer selection, most participants felt that the material was too technical, while two participants felt that there was not enough time allotted for this task.

In summary, without knowing the complete HCM contractor rules used for the reference system selection, and without all necessary input information, it was difficult to obtain the same answer.

3. Work Package 3 - Task Identification

The objective of this part was to take the previous reference system design as specified by the HCM designers, plus the data included in work package 3, and develop generic and reference task lists and assign the tasks to equipment.

Table 6-5. Work Package 2 - Respondent vs. Dynamics Research Corporation Results

Major System Components	DRC	Respondents 1	2	3	4	5	6	Number Correct
AN/ARC-114 R/T	X			X		X	X	3/6
SN 416/APX 76 ECCM	X			X		X		2/6
KYK-13/TSEC Fill	X			X		X	X	3/6
C-2328/GRA-39 SRCU	X		X	X	X	X	X	5/6

The answers to this package were similar to those in Package 1 in that there was a fair amount of subjective matching of tasks to equipment. This again complicated the grading. Therefore, it was decided to check for major categories of equipment only. A major problem arose for the study group here because in Package 3 there were three new major equipment categories (antenna coupler, digital data device, COMSEC), which were not included on the original work Package 2 answer sheet. All three of these categories were missed by almost everyone (see Table 6-6). Only one participant broke his answers into generic and reference categories. Even the HCM designers' answers were not broken down this way. The HCM contractor did not use the workload worksheets for his answers even though they were provided to the participants. Only one participant used the appropriate worksheet from the methodology. This had been done in the training course but was not a requirement of the replication. The level of indenture was again a problem for the study group. Everyone was missing at least some detail.

The HCM designers pointed out during the discrepancies review that this type of effort would typically be a multi-person effort and that missed areas could be picked up within later data packages. Almost all of the participants felt that either not enough detail was provided or the solution did not logically follow from the methodology instructions. Upon clarification of the problems within this element of the replication, it appeared that the participants had a reasonable understanding of how to apply tasks to equipment.

4. Work Package 4 - Reliability and Maintainability (R&M) Determination

In this package the analysts were directed to use given input data and then to perform a reliability and maintainability analysis of the SINCGARS system manpack configuration. The final result of this effort was the determination of the system equipment maintenance workloads. The participants were

Table 6-6. Work Package 3 - Respondent vs. Dynamics Research Corporation Results

Major Equipment Categories	DRC	Respondents 1	2	3	4	5	6	Number Correct
Manpack	X	X		X			X	3/6
Receiver Transmitter	X	X	X	X	X	X	X	6/6
Antenna Coupler	X			X				1/6
ECCM Unit	X	X	X	X	X	X	X	6/6
Digital Data Device	X							0/6
SRCU	X	X	X	X	X	X	X	6/6
COMSEC	X							0/6

to take the tasks and equipment on the workload worksheets, perform the calculations as specified in the instructions, and ultimately derive maintenance ratios (see Table 6-7, column 14, for a sample workload worksheet). This was to be done for three types of systems: a reference system and two proposed systems, one from Cincinnati Electronics (CE) and one from ITT. This exercise resulted in an examination of approximately 300 maintenance ratios for each participant. Unfortunately, wrong frequency information was given in the instructions for using operating hours. The wrong usage metric (annual operating hours) was given for the CE ECCM module. The contractor answer sheets had several problems. General and direct support were interchanged for the reference system ECCM module. CE SRCU answers were given even though the participants were only supposed to use reference system data. A few minor components (e.g., battery) were missing. Most importantly, several answer sheets were wrong and had to be replaced by corrected ones.

In view of the above problems, it was decided to grade the study group based on what they <u>thought</u> was the proper procedure. The use of reference system data for components of the CE and ITT were not included. Because one participant (1) did contact the designers and obtain the correct CE ECCM usage metric, the use of the incorrectly given value was counted as wrong. Table 6-8 gives the percentage of correct answers with clarifying comments. The use of the correct usage metric for the CE proposed system is obvious for Respondent 1. His percentage correct was 94 while everyone else varied between 59 and 71. Several respondents (3,4,5) were missing some system components. Participant 6 disregared some columns on the workload worksheet but still managed to obtain high scores. Similarly, Participant 3 seemed to differ from the HCM designers in his approach but still arrived at correct answers.

Table 6-7. Corrective Maintenance - Workload Worksheet

MISSION SCENARIO: (1) Reference System Manpack V(1)-SRCU Unit

DATE: ______

MAINT LEVEL: (2) ALL

PAGE ___ OF ___

(3) SYSTEM (Maint Level)	(4) TASK EQUIPMENT NOMENCLATURE	(5) FOC	(6) MOS/SL/ASI	(7) MTTR/TASK	(8) # PERS.	(9) USAGE METRIC	(10) MAINT ACTIONS OR FAIL RATE	(11) OTHER ACTIONS	(12) TOTAL ACTIONS	(13) DMMH/TASK	(14) MAINT RATIO	(15) SCENARIO USAGE RATE	(16) TOTAL DMMH	(17) INDIR
Crew/Org	Replace			0.200	1.000	OH	-	-	.000593	0.200	.000119			*
	Repair			-	-	-	-	-	-	-	-			-
	Overhaul			-	-	-	-	-	-	-	-			-
	Test			0.100	1.000	OH	-	-	.001186	0.100	.0001			*
DS	Replace			0.500	1.00	OH	-	-	.000120	0.500	.0000			*
	Repair			1.000	1.000	OH	-	-	.000120	1.000	.0001			*
	Overhaul			-	-	-	-	-	-	-	-			-
	Test			0.200	1.000	OH	-	-	.000593	0.200	.000119			*
GS	Replace			-	-	-	-	-	-	-	-			-
	Repair			-	-	-	-	-	-	-	-			-
	Overhaul			2.000	1.000	OH	-	-	.000059	2.000	.000118			*
	Test			-	-	-	-	-	-	-	-			-

NOTE: Not required, indirect maint. manhours included with MTTR/task manhours because these manhours were derived from MAC Tables.

Table 6-8. Work Package 4 - Respondent vs. Dynamics Research Corporation Results (% Correct-Maintenance Ratios)

Respondent	Reference	CE	ITT	Comments
1	70	94	87	E
2	95	61	94	A
3	95	59	82	A,B,D
4	40	60	95	A,B,E
5	50	71	89	A,B
6	100	71	89	C
$\overline{X}$	75	69	89	

A - Wrong usage metric for CE
B - Missing items - Reference, ITT
C - Missing calculation steps
D - Different calculation procedure than DRC
E - Wrong total actions - ITT, Ref

The study group had several comments on the incorrect and confusing replication instructions. Most commented on the extensive calculations, time limitations, and tedium caused by the task. One participant (3) resorted to using a programmable calculator.

During the discrepancy review, the HCM designers noted that this procedure has now been simplified by using updated LSA data sheets and by automating the worksheet.

Despite all the problems, the number of answers that matched the contractor's calculations were relatively high (generally between 60 and 95%). This indicated that at least for SINCGARS, the study group probably understood how to apply this phase of HARDMAN.

5. Work Package 5 - Design Difference Index (DDI)

The participants were directed to develop the SINCGARS proposed design in the manpack mode for the two contractors (CE and ITT) by evaluating and compiling a list of reference system versus proposed system design differences. The study group was then supposed to determine the impacts on system workload of each design difference. The resultant perturbation values

(PV) were to be used for adjusting the reference system design so that equitable comparisons could be made between the reference and proposed systems.

This task generated the most discussion during the discrepancy review. The discussion centered on the nature of the comparisons. For instance, should a reference system be used "as is" or should there be an adjusted reference system if reference and proposed systems have significantly different technologies and time frames. This question was not addressed during the training course or the replication. Because this problem was discussed earlier in Section V, it will not be pursued here.

As in packages 1 and 3, the work that Package 5 answers were quite subjective (see Table 6-9 for a sample contractor answer sheet). This package had the highest variance among participant answers. The contractor answers had only two PVs. Participant 3 had 30 values. Individual 6 had 16. Participants 4 and 5 had none. Participant 5 left out the ECCM, ECCM Fill, and SRCU subsystems. Individuals 4, 5, and 6 made no reference to the LSA-02 reference data.

It was found in the debriefing that the study group had trouble determining the design differences and did not understand the use of the PV. In summary, it is apparent from the study group feedback and work package answers, that this step could not be closely replicated and further clarification is needed.

6. Work Package 6 - Select and Assign MOS

The objective in this part of the replication was to record the MOS and skill levels that are currently performing each operation and maintenance task for the reference system equipment in column 6 of the workload worksheet. MOS and skill levels were also to be recorded for the contractor proposed systems. Lastly, for those tasks omitted by the contractor, the reference system data were to be used.

Because the study group had previously calculated the column 14 maintenance ratios on the workload worksheets, it is likely that the replication effort would have proceeded more easily if this task had been done earlier. This was reiterated during the discrepancy review. Additionally, it was pointed out that the MOS selection process needs additional refinement by the HCM designers. Presently there are no systematic decision procedures for deciding which tasks are to be matched with the appropriate MOS and skill levels.

Once again, there were problems with the given answers. The grader was not given all the answer sheets. LSA answers were supplied for components where reference data should have been used. Lastly, CE R/T answers were given when the study group had not been given the inputs. As opposed to Package 4, the reference components jointly included in the proposed systems were included in the grading. This inclusion is not very significant (6 out of 151 answers for the CE (4%) and 13 of 141 for the ITT (9%)), but it was done here because the participants were directed to do so in the instructions.

Table 6-9. Sample Dynamics Research Corporation Answer Sheet

CODE	REFERENCE	PROPOSED	DIFFERENCE	SOURCE	IMPACT	PV	REMARKS
8GZZ CE	SN416( )/ APX 76( ) Electronic Synchronizer IFF Gear (ECCM)	ECCM Sidehat	REF: Different type of synchronizer than that of proposed systems but functions similar/R&R tasks performed at D/S Level/Modular type parts CE: Video gating, power supply and filter elements not required in proposed/ separate unit added to R/T/ R&R Tasks done at ORG Level/ Improved R/M/Separate unit instead of single card	Navy 3M Data KC-130F Aircraft R/M Summary Oct. 81 - Sep 82 Harris 3090P R/T Instruction Manual DEP 11-5820-891-10	Decrease CM	-	Utilize CE Predictions From LSA-02
8GZZ ITT	Same	ECCM Module	REF: Same as Above ITT: Video gating, Power Supply and filter elements not required in proposed/single card makes easier access for repair and fault isolation/improved R/M	Navy 3M Data KC-13- F Aircraft R/M Summary Oct. 81-Sep 82 Harris 3090P R/T Instruction Manual DEP 11-5820-890-10	Decrease CM	0.8	Apply to Task Freqs.

All participants primarily had problems with, or could not understand, the contractor MOS selection process. In fact, one individual used predecessor system MOS instead of those of the reference system. Even though it was only necessary to copy MOS from the correct data sheets, the average scores were not particularly high (55-80%) (Table 6-10). Two possible contributing factors are (1) the recurring problems with the methodology instructions and (2) the boredom caused by the tedious nature of filling in approximately 300 MOS and skill levels.

7. Data Package 7 - System/Component Usage Rates

In this package the usage rates for the components of SINCGARS were to be determined. This data is required for column 15, usage rate, of the workload worksheets (see Table 6-7). Because only one value for each component (R/T, ECCM, ECCM Fill, SRCU) was required, this was the most straightforward assignment of the entire replication effort. The entire study group had the correct answers. Note that in doing a firsthand application in the real-weapon development environment, usage data might be difficult to acquire.

Table 6-10. Work Package 6 - Dynamics Research Corporation vs. Respondent Answers (% Correct MOS Answers)

Respondent	Reference	CE	ITT	Comments
1	50	95	79	A
2	77	87	73	C
3	73	79	67	C
4	50	97	63	C,D
5	45	44	91	A,C,D
6	36	85	69	B,D
$\bar{X}$	55	81	74	

A - Missing Reference System R/T MOS.
B - Assumed DRC used predecessor rather than reference.
C - Missing CE or ITT R/T MOS.
D - Missing Reference Components for ITT.

8. Work Package 8 - Determine Workload and Manpower Requirements

The goal of this final package was to determine the workload results and manpower requirements for the reference and proposed systems. The workload results were obtained by multiplying the maintenance ratios from Work Package 4 by the scenario usage rate from Package 7. That result was to be multiplied by the indirect productivity factor (IPF) to obtain the workload results. The next step was to add the workloads, by component, to get the total. The manpower requirements were to be obtained by multiplying the workload totals by one of two manpower availability factors that were supplied by the contractor. Because this last step was trivial, only workload totals were analyzed in detail.

The HCM design team answers had several shortcomings. Calculation mistakes were found that had to be corrected, and LSA data were incorrectly used in place of reference system data. With respect to the study group, the use of wrong MOS was evident for five respondents. Reference data were left out by four of the participants. Four individuals also made calculation mistakes. The participants were confused by the contractor justification for selection of IPF and manpower availability factors. Two also commented on time limitations. Given the above problems, in addition to the problems with the previous packages, it was surprising that the study group got any of Package 8 correct. Actually, the average percent correct was between 25 and 45 (Table 6-11). One individual (2) averaged 69% correct for each of the three systems.

D. QUALITATIVE ACCURACY STUDY

The names of pertinent military personnel were supplied by ARI and the Navy HARDMAN office. These contacts covered a wide range of Navy and Air Force procurement projects that required manpower and training forecasts (Table 6-12). The feedback on HARDMAN with respect to these real-life applications varied from highly positive to negative. It was noted that these impressions could be at least somewhat affected by the personal biases of people contacted. Nevertheless, as a rough estimate of accuracy, it was felt that these contacts were a good initial step.

The Advanced Lightweight Torpedo (ALWT) project logistician was highly favorable (33). He was impressed with HARDMAN in that its initial application could start with very little input data. Its resulting projections appeared to be within about 10% of actual manpower data. His immediate experience applied to the reliability and maintainability areas. He also pointed out that these estimates went through the Navy's Logistics Review Council (LRC) unscathed. This typically happens only thirty percent of the time. Most of those projects that do not pass have unsatisfactory manpower and training estimates. HARDMAN also saved ALWT large sums of money because of its ability to highlight possible problems. These comments were reiterated by the ALWT ILS manager although he added that the HCM was difficult to understand (34). He also pointed out that HARDMAN provides a consolidated data base that facilitates sensitivity analyses. The ALWT and SIRCS MPT logistic element manager felt that once the total integrated methodology (HARDMAN plus training requirements determination plus life-cycle costing) is developed, it will be

Table 6-11. Work Package 8 - Dynamics Research Corporation vs. Respondent Results % Workload Results Correct

Respondent	Reference	CE	ITT	Comments
1	0	70	25	B,C,D
2	86	80	42	A
3	29	60	50	A,D
4	0	10	8	A,B,D
5	29	30	17	A,B
6	14	20	8	A,B,C
$\bar{X}$	26	45	25	

A - MOS Discrepancies
B - Component answers wrong
C - Left out reference maintenance
D - Did not use all reference data for CE or ITT

Table 6-12. Qualitative Accuracy Study Contacts

Project		Contact
SUBACTS	- Submarine Combat System	Training Manager
ALWT	- Advanced Lightweight Torpedo	ALWT Logistician
ALWT	- Advanced Lightweight Torpedo	ALWT ILS Manager
DDGX	- Destroyer	Personnel and Training Analyst
ALWT	- Advanced Lightweight Torpedo	MPT Logistics Element Manager
SIRCS	- Shipboard Intermediate Range Combat System	MPT Logistics Element Manager
VTXTX	- Flight Trainer	Project Manager
Air Force	- ASSET and other similar techniques	ASSET Operations Research Analyst

very useful for the early identification of manpower requirements (35). In comparison with other similar methodologies he felt that HARDMAN was less cumbersome and more accurate. He also pointed out that one drawback of this type of methodology is that it does not interface with hardware design requirements.

The training manager for the SUBACTS program felt that, although the HARDMAN manpower forecasts have been fairly accurate, there were problems in understanding the approach (36). The SUBACTS program brought in an independent contractor to use HARDMAN, which helped make the approach more understandable. Concurrently, the new projections proved to be as accurate as the original forecasts.

One of the DDGX destroyer training analysts has had MPT experience on pilot programs within NAVC, NAVAIR, and NAVLX. He stated that there was no standard, overall methodology for manpower estimates at present although it is planned (by January 1984) to evaluate a Navy program (SYSCOM) with the help of the HARDMAN office. He felt that, although total feedback on HARDMAN has not been received as yet, it is probably quite useful and will have many applications within the Navy (37).

The project manager for the VTXTX flight trainer was too far removed from forecasting to say how closely HARDMAN resembled real life. With respect to other similar methodologies, he stated that it has typically been difficult to match their outputs to actual performance. This has usually been due to the differing ways the methodologies define system components as compared to the actual system design (38).

An operations research analyst at the Air Force's Human Resources Laboratory has been involved with several Air Force projects. She has worked with HARDMAN-type methodologies (e.g., coordinated Human Resources Technology, ASSET) but has found to date they have not been widely applied (39).

E. RESULTS OF MANPOWER SENSITIVITY ANALYSIS

The problem explored in this portion of the reliability analysis was how accurate manning estimates must be in a new system acquisition. Because the penalty and cost of estimation can be quite high, it is important to be clear about the benefits of accuracy and the costs of inaccuracy, particularly when developing a projection technique such as the HCM. Further, because manning is not estimated in a vacuum, it is important to establish whether concentration on accuracy in other related variables will have any impact on the manning estimation.

In this portion of the analysis, permissable error bounds were determined and applied to the SINCGARS program to study the interplay of manning estimate accuracy and the accuracy of other variables. Error bounds were determined through interviews with decision makers involved in program review offices such as the Office of the Secretary of Defense (OSD) or the Cost Analysis Investigation Group (CAIG). For this small study, most of the individuals contacted were associated with OSD. Data descriptive of the SINCGARS system were obtained from the SINCGARS program office. Error

relationships were investigated through the use of an interactive life-cycle cost model developed for the U. S. Navy and adapted to this particular exercise (8).

The overall conclusion of this brief study is that accuracy of manning estimates may not be a significant issue in the development of tools and methods for acquisition support and cost analysis. For example, if manning estimates were scrutinized by the budget controllers and were found to be as poor as the 15% boundaries allow, the error in spare stockage costs (a major LCC variable) would be almost 50%. Therefore, budget controllers would most likely flag other important quantities long before the manning estimates would exceed their permissable limits. This conclusion is explored in greater detail in the following paragraphs.

1. Permissable Error Criteria

The costs of error vary by circumstance and direction. Many believe, for example, that the "cost growth" phenomenon marking system acquisitions of the past decades is partly explained by poor cost estimating in the early stages of acquisition. Nonetheless, this facet of many programs has been a contributing factor to cancellation.

A theoretician would relate the permissable range of error to the trade-off between the cost of error and the cost of reducing it. In the case of manning estimation error, the major variables have to do with establishing appropriate personnel pipeline flows at the right times to make required resources available on time. Conversely, excess flows are to be avoided. When these flows are of the wrong size, costs are incurred in adjusting them. Costs of concern to the Department of Defense come in two forms: dollars and readiness. These are looked upon differently by decision makers.

OSD (or CAIG) personnel responsible for questioning the estimates of cost and support requirements for new systems look for (1) gross error in cost estimates and (2) errors in readiness-critical quantities. If total dollars is the only issue, an estimated error of about $50 million (in an estimated quantity) seems to be required before decision makers are willing to slow down the progress of a program to check for more accurate estimates. By the same token, very small amounts of dollars may be involved in such decisions if the variable being estimated is <u>critical</u> to <u>readiness</u>. Here the rule is that the cost estimate may not be off by more than about 15%, regardless of how small the total dollar amount is.

The mechanism by which these limits are employed is the application of experience and judgment to assess cost projections from program offices. The decision makers queried have all studied the relevant issues for many years on a variety of systems. It was assumed that their experience provided them with a reasonable, independent assessment of the value of specific quantities of interest. If their assessments differ from those presented by program offices by more than the amounts indicated above, this gives rise to a question and request for further analysis.

To formalize this mechanism, it can be compared to a statistical test of hypothesis. The decision maker's estimate is the population mean and the

program office submission is the sample mean. The decision maker acts as if a 15% difference is sufficient to reject the hypothesis that the sample is drawn from the same population.

2. Results of the Analysis

The procedure followed was to drive manning to ±15% of its value in the baseline estimate by varying several different input values. The results for MTTR, MTRR, MTBF and usage rate are shown in Figure 6-1. The figure shows the positive error boundary for manning on the vertical axis as a function of various LCC input values on the horizontal axis. The closer the plot of each variable is to the horizontal axis, the less responsive manning is to variations in that variable. Reading the figure, the farther to the right a line intersects the +15% line, the greater the error in that variable necessary to produce the fixed error in manning.

The most powerful variable is usage rate because this simply acts as a scalar against all demand rates. Failure rate (the inverse of mean time between failure) is the next most powerful determinant, driving manning to its lower boundary at half its baseline value. The two maintainability variables are the least powerful, mean time to remove and replace having a greater effect than mean time to repair. This is explained by the fact that in the basic data set, the latter is only one hour while the former is three hours. This difference is accentuated by the fact that four of the LRU are coded discard at failure, which means that they will be removed and replaced but not repaired.

Figure 6-2 is a plot of life-cycle cost variation against manning levels produced by changes in the four major variables. It is clear that usage rates have a strong effect throughout the cost estimate while reliability and maintainability statistics have a much smaller influence. Notice also that mean time to repair, even when driven to zero, cannot produce the -15% manning error.

Another comparison of value is the different effect of MTBF errors on manning and spares. The error bounds on spares are reached at 86.7% and 118.5% of baseline MTBF. The corresponding manning error, however, is only 4.7% and -4.6% at these limits. To reach the ±15% manning errors, the multiples required are 66.8% and 200% of baseline MTBF. These relationships are illustrated in Figure 6-3. Thus, it appears that for this particular case, reasonable scrutiny of the spares cost estimate (and hence reliability) would be likely to confine the value of the manning error well within prescribed limits. Similar comparisons cannot be made for the maintainability variables because they do not affect readiness-critical outputs other than manning and training.

The remaining possible source of excess error in manning estimates is from joint errors in input variables. This problem can be illustrated by joint errors in maintainability and reliability data. MTRR is used for the former and MTBF for the latter.

Figure 6-4 illustrates the accelerated effect of joint errors in MTBF and MTRR in the presence of errors in the manning variable. The two graphs are the locus of manning errors produced by different levels of error in MTRR,

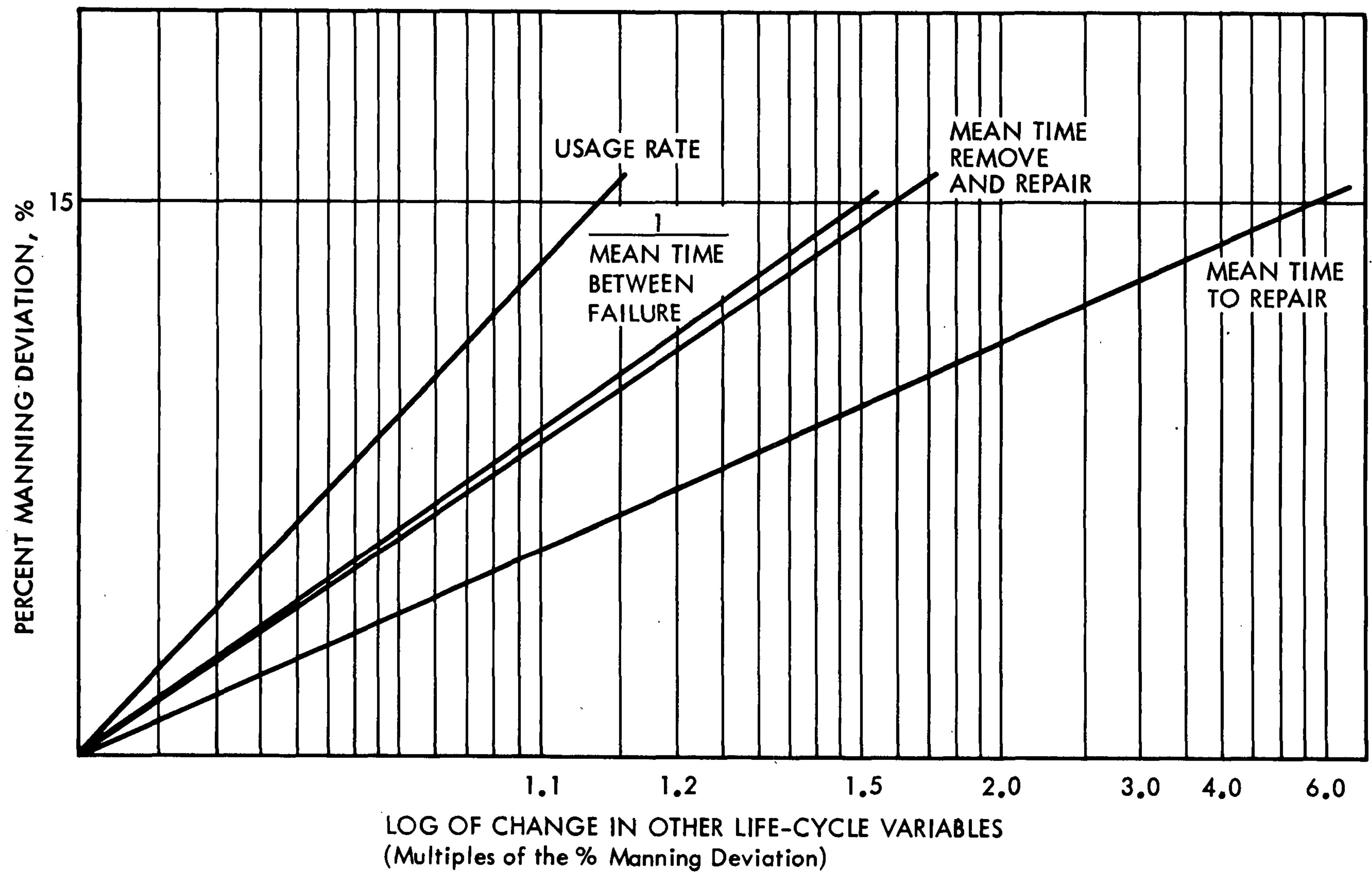


Figure 6-1. Errors in Input Variables Producing 15% Error in Manning

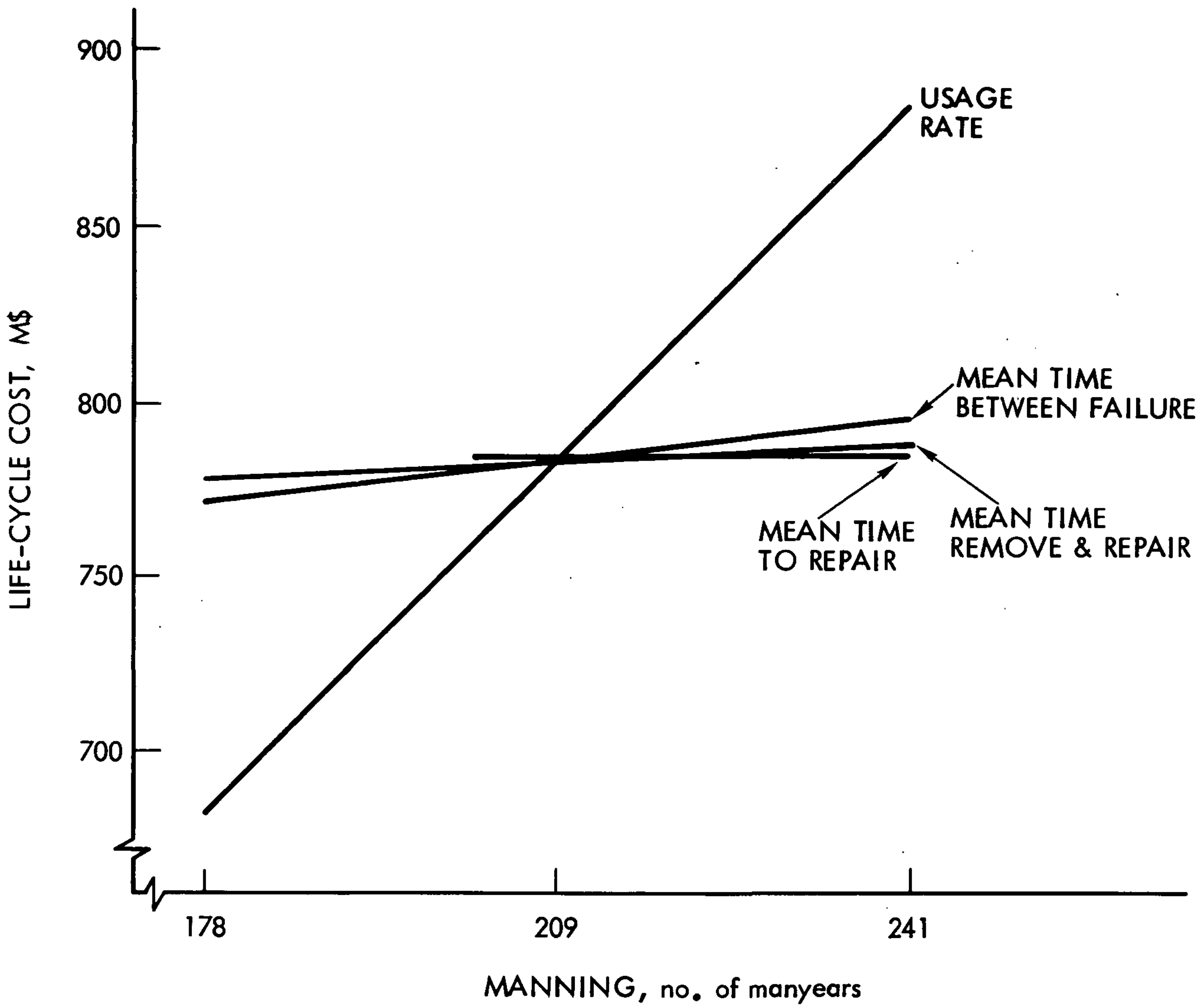


Figure 6-2. Response of Life-cycle Cost and Manning to Equal Changes in other LCC Variables

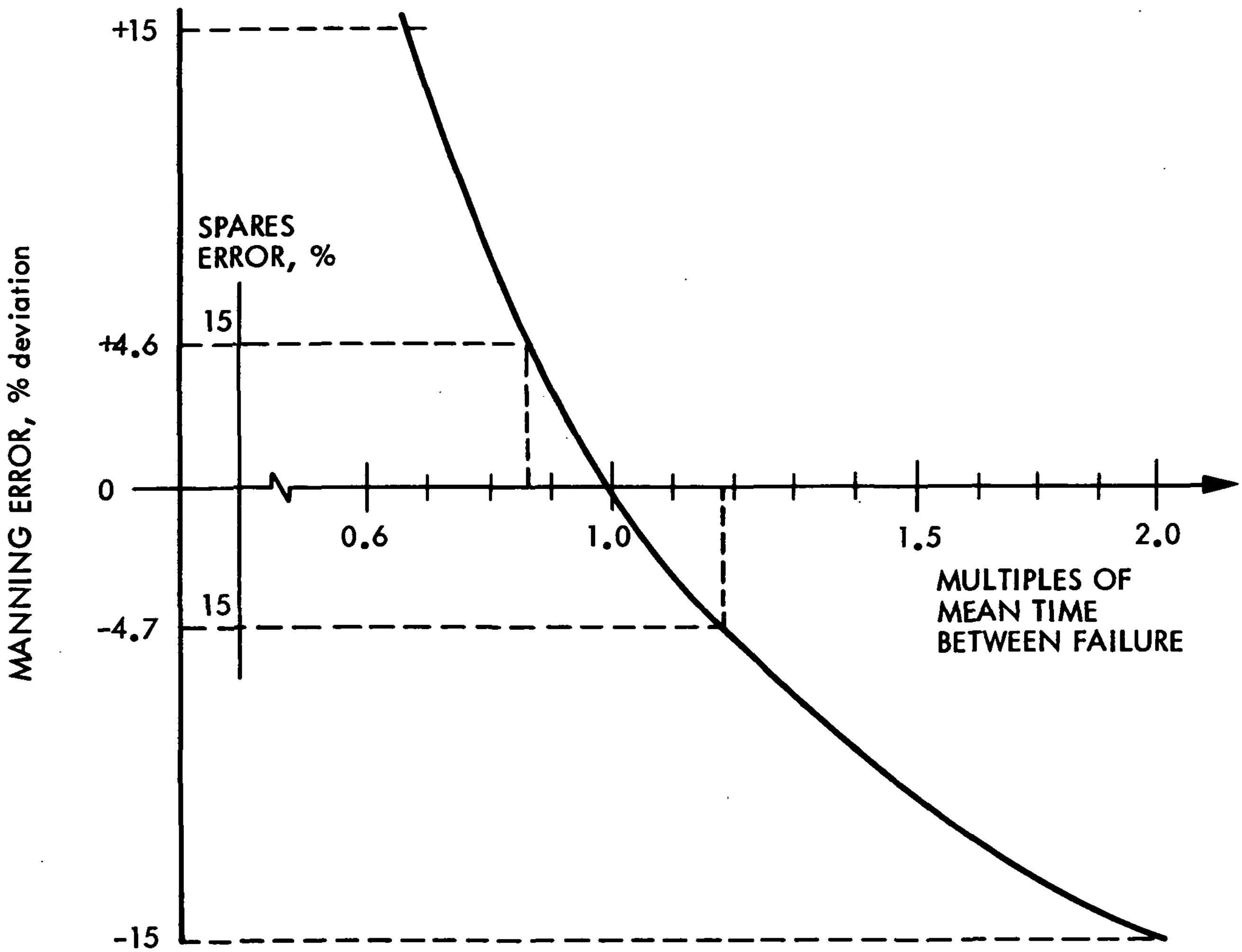


Figure 6-3. Comparison of Spares and Manning Errors

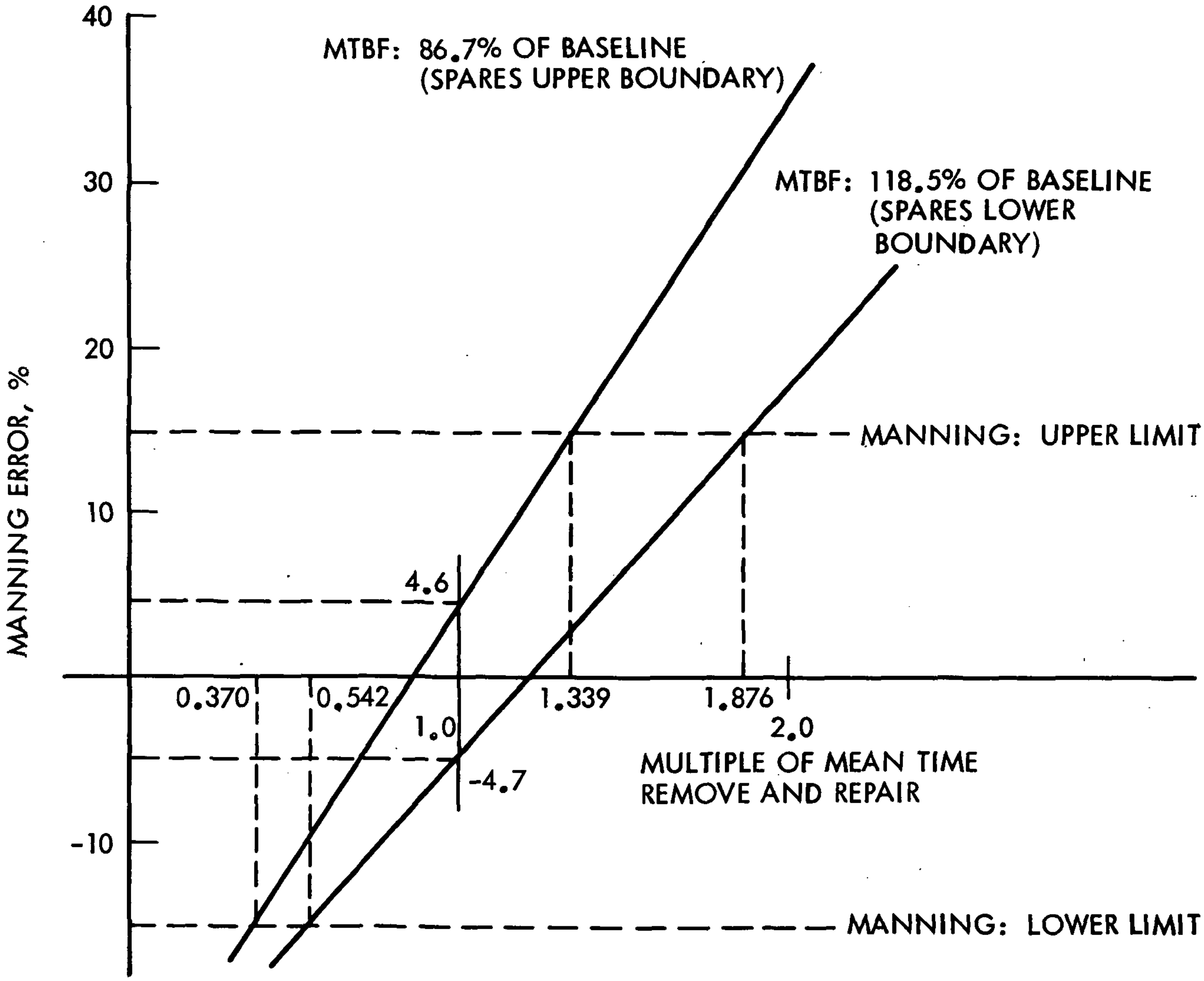


Figure 6-4. Relationship of Joint Errors to Manning

given a certain error has already occurred in MTBF. The graphs have been drawn for those values of MTBF that produced the upper and lower boundary errors in spares estimates.

Notice that even under the joint error condition, a relatively large error in MTRR is required to produce a 15% error in manning. For an MTBF (118.5% of the baseline) that produces a 15% underestimate in spares, MTRR must also be understated by almost fifty percent (0.542) of its true value to produce a manning estimate 15% lower than its true value. Under the same MTBF error an overestimate of 87.6% in MTRR is required to produce a 15% overstatement of manning requirement. For an understated mean time between failure (86.7% of the baseline), the MTRR must be misestimated at about two thirds its value (0.37) and almost a third again its real value (133.9%) to produce manning estimates off by minus and plus 15%, respectively. This one example suggests that manning may not be a particularly sensitive variable in comparison to other dependent LCC variables.

F. RELIABILITY IMPLICATIONS

1. Internal Reliability

The four major findings of the SINCGARS replication were as follows:

(1) There were problems in understanding how to construct the reference system.

(2) There was confusion over the selection and use of design difference indexes, perturbation values, and indirect productivity factors.

(3) There was a lack of understanding of MOS/skill-level determination.

(4) It was apparent that this type of analysis should be performed by a multidisciplinary team, not one analyst.

Among the causes for these findings, beyond the general problems of lack of methodology clarity and inaccuracies caused by not having the technique automated, were problems with the instructions, insufficient or missing supplemental input data, and excess emphasis on calculations instead of reasoned judgments. It was also apparent that the replication deviated too much from the training course content. Additional constraints included incorrect answer sheets upon which later analyses were based, syntax differences in the subjective work packages, and the tedium brought on by the enormous quantity of answers required by Work Packages 4 and 5. Interestingly, the average number of answers that matched the HCM design team was high (78% in Package 4, 70% in Package 6) in some of the packages. However, in the all-important Data Package 8, only 32% of the answers matched the corrected contractor response. This is a function of both the HCM clarity problem and the snowballing effect of previous administrative irregularities already present in the inputs of Package 8. Even with all the problems previously discussed, the study group appeared to understand how to apply HARDMAN to SINCGARS within the regulated

atmosphere of the replication. This finding was derived from the reasonably good performance on roughly half the data packages and the apparent improvement in methodology comprehension, once the discrepancies review conference was held. It is probably only now that the designers understand all of the problems that existed within the replication. If the original replication were used as a pilot study, a comprehensive and consistent reliability check could be performed.

2. Qualitative Accuracy Study

It seems that some of military contacts who deal with manpower and training have somewhat consistent opinions with the results of the face reliability and replication analyses. That is, the methodology is complicated and hard to understand, but when understood and applied correctly, has the potential to provide reasonable manpower and training forecasts for new procurements. This difficulty in understanding HARDMAN negatively influenced some of the personnel queried, or else others surmounted this obstacle and were able to make good use of the technique. It can be conjectured here that the comprehension difficulty experienced by the personnel contacted is similar to the problems encountered during the replication experiment. Once the methodological loose ends are corrected, it appears that HARDMAN could have widespread acceptance.

3. Manpower Sensitivity Study

The sensitivity analysis suggests that manning estimates may be fairly robust; they may not be as responsive to errors in input variables as the other important LCC elements. Because several of these quantities, such as MTTR and MTBF, are scrutinized for accuracy during the review process, and because they are more responsive, it appears likely that errors in inputs will be detected through them before they drive manning estimates out of the permissable boundaries.

With regard to the data that drive these estimates, the results suggest that it would be unwise to devote extensive resources to their refinement for the purpose of improving manning estimates. The more serious sources of significant error in manning estimates that can be isolated from this study are the inappropriate selection of an operating scenario or deployment plan. The TRADOC and DARCOM communities control cost and manning estimates to a far greater extent than normally realized. By setting the number to be purchased, the number of operating units, and the hours of operation for the equipment, the program offices have the largest single effect on estimated quantities of anyone in the design process. Because early in the acquisition process these values are frequently not known with any precision, they are often considered unimportant when, in fact, they are pivotal LCC elements. For example, a system of which 100 will be purchased should be designed and built differently from one where 10,000 will be built. As a second example, usage rate differences of plus and ± 13% will produce error in manning estimates ±15%. These can be produced through an error in the estimated hours of operation per year or in the number of units to be purchased. If both are off

by 6.3% or more, then the joint effect on usage rate will be 15% or more and the manning error will exceed the permissable limits. These remarks should be taken as a caution to program offices to devote the time and energy necessary to establish reasonable, stable values for these variables. Understanding that the sensitivity analysis provided here is somewhat limited by (1) the sample size and variety of acquisitions studied and (2) assumptions concerning the use of Navy billet data as representive of the Army billet structure, the findings are significant enough to warrant repeating the analysis once the Army has its own billet costing system completed.

SECTION VII

CONCLUSIONS AND RECOMMENDATIONS

A. OVERVIEW

The preceding sections provided the findings in the four major validity areas of face, internal reliability, event-series, and qualitative accuracy. At the end of each section, the validity implications were assessed, along with supporting rationale. In this last section, the findings are first pooled and then summarized to illustrate the strengths and common major weaknesses that became apparent after examining and comparing all the validity implications. Next, the resolution of these common problem areas is addressed within the context of (1) the ranking of the weaknesses as a function of the user requirements and their impacts on the accuracy of the methodology; (2) the practical aspects of improving weak areas in terms of difficulty and potential for other organizations besides the original designer to adopt the technique; and (3) the reasonably low requirement to have extremely accurate MPT projections. Ultimately, a condensed, prioritized list of weaknesses and recommended corrective actions is provided. Additionally, follow-on study areas deemed important to closing out issues that could not be addressed within the time and budget constraints of this evaluation are also recommended.

B. SUMMARY OF RESULTS

In total, the HCM proved to be reasonably sound. Table 7-1 summarizes the strengths. The net strengths were based primarily on the high degree of conformance with the user requirements, the reasonable similarity to other MPT modeling processes, and the closure of eighty-five percent of the audit issues. It was also promising to discover that the projections did not have to be extremely accurate, considering the remaining twelve to fourteen problem areas that were found to potentially affect the accuracy and credibility of the projections. The potential concerns or problem areas uncovered, which generally spanned all the user requirements, operational, and reliability analyses, are shown in Table 7-2.

C. PRIORITIZATION OF VALIDITY ISSUES

Before any recommended revisions to the methodology can be made, it is essential to examine each of the issues from Table 7-2 and weigh their importance to meeting the Army's MPT needs and their implications relative to effecting the accuracy and usefulness of the projections. It is important to recognize in the near term that the methodology is reasonably sound. It is equally important to know the major limitations and the supporting fact that allowances can temporarily be made for some of the limitations in light of the inherent acceptable error bounds on the manpower projection. For the near and intermediate terms it would be useful to improve those areas most important and amenable to immediate correction, followed by a plan for improving the remaining far-term areas, perhaps requiring more supporting data.

Table 7-1. Net Results of HARDMAN Evaluation

Evaluation Area	Net Results
User Requirements	Technique complied with majority of mandatory user needs
Operational Analysis	
Comparison with other MPT methods	Methodology conformed with other known, accepted MPT modeling schemes and data foundations
Audits	Methodology demonstrated sound logic and reasonable results for 85% of test issues examined (remaining issues considered reparable in near term)
Reliability Analysis	
Internal reliability	Test group correctly replicated half of selected test points (two of four remaining test points found to be repeatable after clarification)
Qualitative Accuracy check	Two of nine individuals having experience with HARDMAN applications indicated a rough accuracy of 80-90% with actual manning requirements; remaining individuals had insufficient experience to comment
Event Series Validity	Manpower variable found to be least sensitive of all life cycle cost variables, demonstrating good utility of existing methodology even without near-term improvements

Table 7-2. Common Validity Issues

Methodology Step	Validity Issues
Step 1 Data base construction and functional requirements	No firm criteria for selecting, altering, manipulating, or rating data sources
	Unclear indication of functional-requirement level of indenture
Step 2 Build reference system and establish manpower/ skill requirements	No firm guidelines for constructing reference system (particularly when modeling two widely varying proposed designs)
	No consideration given to observed reduced manpower at end points of life cycle
	No firm range and criteria for selecting design difference indices (perturbation values), induced failure factors, or indirect productivity factors
	No complete means provided for equally comparing reference and proposed technologies
	Incomplete guidelines provided for selecting MOS/skills
Step 3 Determine training requirements	No quantitative means of differentiating between critical/non-critical tasks and resultant impact on training
Steps 4 and 5 Determine personnel requirements/ shortages	Projection does not consider manpower available at actual time of system deployment
Step 6 Perform tradeoff analyses and present results	Unstructured tradeoff process
	No indication provided for either relative credibility of projections or best estimate for manpower planning
	Incomplete life-cycle cost analysis
	No standardized assessment of study weaknesses and proposed resolution actions
Overall methodology	Low usability by anyone other than a well-seasoned, multidisciplinary team

1. Near-term Issues

The issues having both sizeable user value and accuracy implications, and jointly found amenable to solution within the immediate one-year time frame were as follows:

(1) No standardized criteria for selecting, altering, manipulating, or rating data sources.

(2) Lack of proper level of indenture for functional requirements.

(3) Insufficient guidelines for constructing reference system.

(4) No consideration for reduced manpower demands at system life-cycle end points.

(5) Unequal comparison of perturbed state-of-the-art technology against new proposed designs.

(6) Lack of guidelines for selecting MOS and skills.

(7) Unstructured tradeoff process.

(8) No credibility indication of projections.

(9) Non-standardized assessment of study weaknesses and resolution actions.

Logic and credibility issues such as items (1), (3), and (5) above, are probably most important because they affect both the accuracy and usefulness of the methodology. Although removal of these problem areas would not guarantee improvement in absolute accuracy, it would certainly provide the users with a better subjective, relative indication of accuracy to aid decisions on budgeting of additional hardware tests or favoring one projection over another for planning purposes until additional information is received.

All of these items were considered candidates for immediate resolution because elements of the solution for each of the issues often already existed in both the HCM design team and the Navy concerning the relative quality of various data sources (31, 40). For example, actual field or controlled collection data probably ranks highest on the list of preferred information for modeling new system performance because of its maturity, followed by operational or field-test data (reasonably mature), development test data, and free-flow or semi-controlled data collection information (limited sample size); and finally, contractor estimates (no test or sample data).

As with the inherent experience available on data sources, it was discovered that solution structures similarly existed for items (3) and (5) above. The use of two reference systems to model two widely varying contractor designs was introduced earlier in Section V-F (the SINCGARS audit). Because the structure already existed for perturbing historical predecessor component data to fill data gaps in the proposed system, it

appeared that a simple extension of the same procedure would allow a "top-level" comparison of the total predecessor and proposed systems on an equal basis.

The next near-term priority closely associated with credibility is the resolution of potential error sources. Items (2), (4), and (6) serve as potential error sources and therefore have accuracy and credibility implications. As indicated in the preceding paragraphs, it was learned that much of the solution framework already existed within the joint experience of the HCM design team who normally perform the HARDMAN analysis (34). The reduced end-point manpower demand issue, item (4), was considered a fairly simple error source to correct, considering that the deployment period and life cycle could be broken down into yearly time periods to be sensitive to the gradual buildup or tapering off of systems. Item (6) above, was another near-term issue that was found easily rectified based on knowledge obtained at both the audits and discrepancy review.

The final near-term priority area is the resolution of some of the ambiguity issues. Items (7) and (9) are somewhat linked together and are rated as the last priority because their solutions serve more to improve the clarity of the process and projections than to contribute directly to accuracy and credibiity. Again, because the solution components for listing all potential tradeoffs, weaknesses, and proposed actions already existed to varying degrees, it was felt that these adjustments to the methodology could be a simple enhancement to the decision-making quality of the technique.

2. Intermediate-term Issues

Some of the validity issues discovered during the evaluation were found to have accuracy implications, but, upon closer examination during the audits and SINCGARS discrepancy review, were also found to be not amenable to immediate solution. Although some data and models were available and appeared to represent means of closing the issues, it was obvious that a certain amount of additional research and methodology restructuring were required and would probably consume one to two years of effort. The issues from Table 7-1 that are relevant to this intermediate category are as follows:

(1) No firm range and criteria for selecting perturbation values, induced failure factors, or indirect productivity factors.

(2) No consideration for manpower availability at the projected system deployment date.

(3) Incomplete life-cyle cost analysis.

In line with the reasoning provided earlier, items (2) and (3) above would have to be given highest priority because they both impact the accuracy and credibility of the projections. For both of these issues modeling processes, introduced earlier in Section V, have already been developed and with slight redesign could be incorporated in the existing methodology. Item (1) is fairly important because it could represent a major error source. Of

the three different types of factors, the perturbation value is probably the most crucial element. Some information presented during the SINCGARS discrepancy review is available to help define the problem of determining what can reasonably be expected regarding improvements in new technology performance. The induced failure and indirect productivity factors were considered slightly larger problems because it is difficult to determine when mistakes in selection of an arbitrary value for either one will generate a serious error in the outcome.

3. Far-term Issues

Some of the validity issues uncovered were found to require a substantial amount of data and time (probably about three to five years) to resolve them. In most cases the issues, although important, only surfaced in either the user requirements or the operational analysis and were therefore of a singular nature. The issues fitting in this category were as follows:

(1) No quantitative differentiation between critical and non-critical tasks.

(2) Incomplete consideration of demographic data such as age, sex, or education.

(3) No consideration of the manpower impacts of other emerging systems.

(4) No consideration of major socioeconomic fluctuations on manpower availability.

Probably the largest potential error source is item (3) because the overall acquisition and planning process for new systems spans several years. Consequently, new concepts being approved have a very good chance of overlapping each other in their respective design and support planning stages. The remaining items are fairly equivalent in their level of importance.

Great care was taken in the preceding paragraphs to refrain from including suggestions for improvements to concentrate on presenting a clear rationale for the near-, intermediate-, and far-term ordering of the various problem areas. Having prioritized all the various validity issues as a function of their potential for weakening the methodology and ease of solution, the final step is to explore sensible solutions.

D. RECOMMENDATIONS

One way to develop a plan for implementing recommendations is to first convert each issue into a positive proposed action and then summarize the total scope of intended actions. Table 7-3 first provides a summary plan for improving the existing methodology, followed by a detailed discussion of each suggested corrective action.

Table 7-3. Recommended Plan for Improving HARDMAN Methodology

Prioritized List of Recommendations	Potential for Improving Methodology					
	Near-Term		Intermediate		Far-Term	
	High	Med.	High	Med.	High	Med.
Establish criteria for rating, selecting, altering, or manipulating data	X					
Provide indication of credibility of projections	X					
Establish top-level method for comparing technology of total reference/baseline and proposed systems	X					
Provide better guidelines for constructing reference systems	X					
Firm up guidelines for functional-requirements level of indenture	X					
Provide a better structure for MOS and skill selection	X					
Reduce MACRIT manpower projection down to one- or two-year projections to be sensitive to lower end-point demands		X				
Provide a more structured tradeoff process		X				
Establish standardized assessment of study weaknesses and resolution actions		X				
Project manpower availability out to actual system deployment date			X			
Provide more complete lift-cycle cost/tradeoff analysis			X			

Table 7-3. (Cont'd)

Prioritized List of Recommendations	Potential for Improving Methodology					
	Near-Term		Intermediate		Far-Term	
	High	Med.	High	Med.	High	Med.
Firm up ranges for perturbation values, induced failure, and indirect productivity factors				X		
Incorporate potential manpower impacts of other emerging systems					X	
Provide quantitative differentiation betwen critical and non-critical tasks						X
Incorporate more demographic data into personnel/availability projections						X
Consider major socioeconomic fluctuations in manpower availability projection						X

The following paragraphs develop each of the recommendations in Table 7-3 by suggesting possible corrective actions. First, consideration is given to the methodology design, followed respectively by suggested training for potential HARDMAN analysts as well as follow-on research.

1. Methodology Design

Because the key credibility issues were primarily centered in the near- and intermedite-term time frames, the following discussion focuses on those recommendations that fit in that one- to two-year time span. Far-term corrective actions are discussed in the "follow-on" portion of this subsection.

a. <u>Suggested Corrective Actions for Data Management and Credibility Indication</u>. It is generally the intent of any modeling technique to act as a guide or tool to assist decision makers. As suggested earlier in Section IV, the Army users indicated a need to be able to apply HARDMAN as an assist to the ASARC or program management budget decisions. Paramount to making program direction, budget priority, and type manpower decisions is

understanding both the kinds and quality of data employed in the analysis. Consequently, a simple data rating matrix is suggested as a means of both summarizing the net credibility of the projections in the executive summary of HARDMAN applications as well as aiding the construction of the consolidated data base in Step 1 of the methodology. Table 7-4 is provided as an example.

Table 7-4 basically applies to the proposed design. The listings of both the weighting criteria and data source quality were based on the joint experience of the Navy and contractor HARDMAN analysts. The table has considerable flexibility in that the analyst can fill it out solely for the proposed system if the predecessor reference or baseline system data are good or evaluate both the reference and proposed systems separately if each contains suspect information. Similarly, the data evaluation can be done on a component-by-component basis. In all these schemes the analyst merely has to indicate the availability, maturity, and type of data employed that automatically places the outcomes in a low, marginal, or good credibility quadrant. Once the data source(s) has been located, the remaining table elements can be answered. Probably the final credibility assessment will span two quadrants (i.e., low to marginal or perhaps marginal to good). Ultimately, a summary table such as Table 7-4 could provide an overall assessment of the data and projections to the decision makers so that MPT planning and budgeting can always be supported by the more reliable projection throughout the system development phases.

Processes for changing or manipulating data were also recommended as part of the suggested improvements. Although not as complicated as the data-rating scheme, a simple delineation of helpful hints for when to alter data inputs (along with supporting examples) is necessary to help clarify the data management process in Step 1 and improve the audit trail. Based on the findings of the previously described audits, the basic guidelines for handling data appear to be as follows:

(1) When building the consolidated data base, first check the proposed system operator and maintenance data for completeness; if data are missing for any components, select appropriate component data from a similar existing system, perturb the data per instructions provided in Step 2 of the methodology, and complete the proposed system data set (see the SINCGARS HARDMAN results for an example) (28).

(2) All proposed system data inputs should be filtered by a group of experts to establish confidence that the data are reasonable. For example, basic maintenance repair times should be checked to determine if sufficient time is allowed for obtaining test hardware and tools by comparing them against similar tasks on predecessor components. If erroneous failure rate, indirect productivity, or induced failure data are encountered, replace the data with comparable historical values (best choice) or select appropriate values from the original minimum performance criteria stipulated in the request for proposal, RFP (next best choice) (see the RPV HARDMAN results for an example) (29).

Table 7-4. Credibility Rating of Data Sources and Manpower Projections for Proposed and Reference System Comparison

<table>
<tr><th rowspan="2">Data-Weighting Criteria</th><th colspan="5">Potential Data Sources</th></tr>
<tr><th>Contractor Projection</th><th>Field Data (Free-Flow or Semi-Controlled SDC)</th><th>Development Test Data</th><th>Field-Test Data (Operational)</th><th>Actual-Field Data (Controlled SDC)</th></tr>
<tr><td>Small amount of equivalent operational/maintenance data available

Operational/maintenance data available is not mature

No clear functional/component comparability

No clear operational similarities

Major projected change in technology and maintenance philosophy

Major change in task allocation due to maintenance philosophy

Major change in operating environment</td><td colspan="2">Low Credibility</td><td colspan="3">Marginal Credibility</td></tr>
<tr><td>Reasonable amount of equivalent operational/maintenance data available

Operational/maintenance data reasonably mature

Good functional/component comparability

Reasonably close operating scenarios

Evolutionary change in technology and maintenance philosophy

No major change in task allocation

No major change in operating environment</td><td colspan="2">Marginal Credibility</td><td colspan="3">Good Credibility</td></tr>
</table>

(3) Where necessary, it sometimes saves time to use more recent historical data in the data base because it is easier to collect. For example, if the more recent data are component test data, then a sample sensitivity study should be conducted to determine whether the less mature (but easier to obtain) test data produces significantly different projections than the older, more mature (but harder to gather) historical data. If not, then replace the historical component data with the comparable test data where appropriate (see the RPV HARDMAN results for an example) (29).

(4) Occasionally, it may be difficult to find a predecessor duplicate of a new proposed component. In this situation a larger or smaller scale component with similar design characteristics may be used in the consolidated data base as a last resort. However, it is extremely important to rate the credibility of these data in terms of both operational similarities and environment (see RPV HARDMAN results for an example) (29).

b. Suggested Corrective Actions for Perturbing Reference System to Model New Proposed Design. A framework for perturbing predecessor data to fill gaps in the proposed system data base was summarized earlier in the audits. To provide the decision makers with a better means of evaluating the credibility of contractors' projections, it is necessary to compare both the total reference and proposed designs on an equivalent technology basis. In support of the "evolutionary" technology growth concept, several studies have been done which suggest that industry is often too optimistic about new technology performance (42). Regardless of the fact that much of the overly inflated performance is sometimes derived from inadequate testing, it seems that a 20% improvement in reliability or performance can reasonably be expected (41,42). With respect to Step 2 of the methodology, a simple top-level adjustment of the predecessor reliability and maintenance data might be structured according to the following guidelines:

(1) If the design difference indicates a positive improvement and the operating environment for the new component is not as harsh as the predecessor component, then employ a 20% increase in reliability with a "less than" or "maximum" label on the manpower projection (e.g., < 5,000 operators required).

(2) If the design difference indicates a positive improvement and the operating environments are essentially the same, increase the component reliability by 20%.

(3) If the design difference is insignificant, or the positive design improvement is offset by a harsher operating environment, then leave the reliability and maintenance data the same.

(4) If the operating environment is considerably harsher than the predecessor system and the design and functional differences are insignificant, then do not perturb the predecessor data, and indicate with good confidence that the resulting manpower projections represent a minimum (e.g., a minimum of 5000 operators are required; or, the operator requirement is $>$5000 people).

With these indications on the manpower projection for the updated predecessor or baseline design, one can start to identify whether the contractor projection for new technology performance is reasonable because the projections will either converge or diverge. Along with the earlier credibility ratings on the various kinds of data, the decision makers have a better means of making budget decisions in support of the revised predecessor data or the contractor projection.

c. Suggested Corrective Actions for Constructing the Reference System. During the audits it was discovered that the HCM designers used a more sophisticated way of selecting predecessor components to build the reference system than explained in the methodology. The following additional steps are suggested to help clarify and better structure the Step 1 reference system construction process:

(1) Include a complete listing of documents that help select predecessor components similar to the proposed system (e.g., U.S. Army Field Manual 24-24, Washington, D.C., 20 May 1977; Department of Army (DOA), Aviation Electronics Configuration Directory, December 1970).

(2) Include a listing of typical Army and industry technical contacts (by organization and division) in various component classifications (e.g., radios, surveillance sensing, etc.) that can confirm similarities or differences between the reference and proposed systems.

(3) Employ two reference systems if two proposed systems, although functionally similar, employ completely different technologies (e.g., a Howitzer versus a rocket launcher).

d. Suggested Corrective Actions for Functional-Requirements Level of Indenture. Similar to the preceding reference system suggestions, the audits revealed that the HCM designers employed a decision process which, although simple, provided more functional and task requirements guidance than the published methodology. It is suggested that the following steps be included in Step 1 of the methodology to better define the level of indenture of the functional requirements:

(1) Go to a level in which the associated component tasks stop branching off (i.e., new tasks requiring different people cannot be identified, such as a mechanic who can repair both the truck engine and the chassis).

(2) Go to a level in which no further technology differences can be delineated between components.

(3) Go to the same level as available sample predecessor component maintenance data in the consolidated data base.

e. Suggested Corrective Action for MOS and Skill Selections. The audits discovered that the cookbook approach outlined in the methodology was not complete. The additional step not included in the methodology, which ensures the proper matchup between tasks and skills, is the use of experts from various proponent schools. Therefore, it is suggested that the methodology include a list of Army proponent school contacts (for all types of component groups and technologies) that can confirm or alter the task and skill selections as necessary.

f. Suggested Corrective Action for Potential End-Point Manpower Errors. The solution to the end-point manpower shortage problem was outlined earlier in this section. The basic solution revolved around shortening the intervals between manpower projections, particularly when considering manpower demands of emerging systems during the early acquisition or later life cycle phases. Figure 7-1 graphically displays the solution by showing MACRIT projections at one-year increments during periods of rapid changes in deployment and attrition, and the typical long term MACRIT rectangular projection for the mid-cycle, steady-state period.

g. Suggested Corrective Action for Structured Tradeoff Process. To instill confidence in the reader that the methodology encompasses all possible tradeoffs, a simple table could be constructed as shown in Table 7-5. Table 7-5 could be placed in the executive summary as a means of displaying (1) the range of potential tradeoffs that the methodology could provide and (2) the actual tradeoffs conducted for a particular application

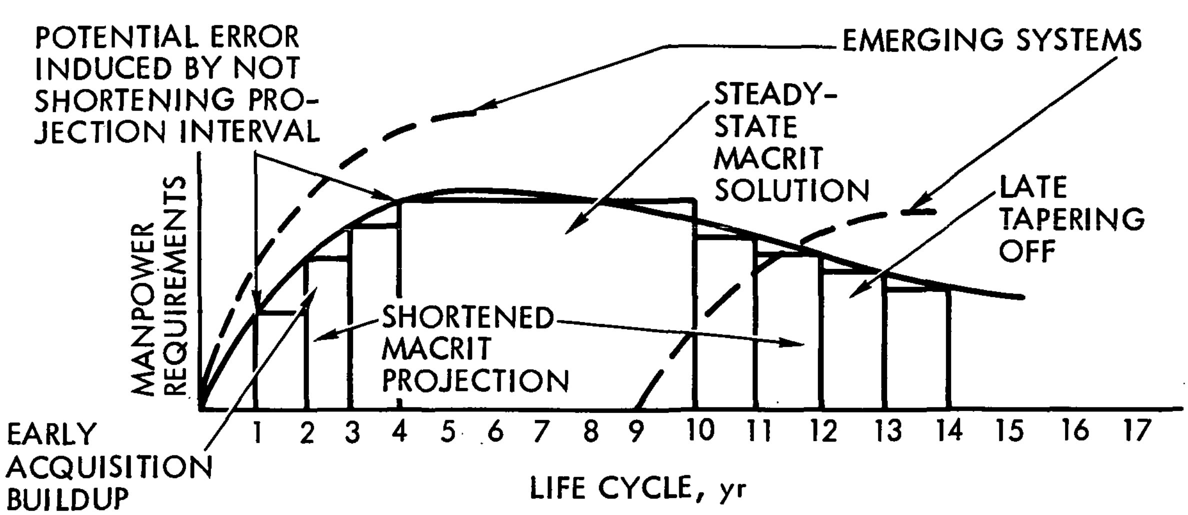


Figure 7-1. Revised MACRIT Manpower Projection

Table 7-5. HARDMAN Methodology Tradeoffs

LIFE-CYCLE COST TRADEOFF PARAMETERS	INCREASE BUDGET CEILING	INCREASE RELIABILITY	INCREASE SPARES	INCREASE MANPOWER	INCREASE SKILLS	INCREASE TRAINING	INCREASE TECH PUBS	INCREASE SSE	INCREASE TOOLING
DECREASE BUDGET CEILING									
DECREASE RELIABILITY									
DECREASE SPARES									
DECREASE MANPOWER									
DECREASE SKILLS									
DECREASE TRAINING									
DECREASE TECH PUBS									
DECREASE SSE									
DECREASE TOOLING									

as constrained by time or the sponsoring agency. The actual tradeoffs explored would be indicated by placing X's in the appropriate slots on the matrix. It should be noted that Table 7-5 is also useful if it is desired to display a clean summary of the various parameter sensitivities. Typically, the sensitivities would be indicated by a relative percentage change (e.g., a 1% decrease in reliability results in a 10% increase in manpower). These more detailed cost sensitivity relationships could be summarized by placing the percentage "deltas" in the appropriate matrix slot. For example, continuing with the reliability illustration, one could read horizontally across the matrix and immediately see the net impact on the other LCC variables. This more detailed cost-sensitivity matrix could be used to cite pivotal cost and tradeoff benefits and jointly close out Step 6, tradeoff considerations, of the methodology.

h. Suggested Corrective Action for Summarizing Study Weaknesses. Although listing study weaknesses is a simple procedure, it is extremely important information for decision makers. In conjunction with a

systematic listing of weaknesses, it is also important to suggest possible resolutions. For example, it is perfectly feasible that both the reference and contractor manpower projections could have "low-to-marginal" credibility ratings assigned because of poor or insufficient data. Consequently, the data problems would be listed as weaknesses and a suggested resolution might be to fund test programs for the major components that are driving the projection credibility down. A simple, dual-heading table consisting of "Major Study Problem Areas" and "Suggested Resolution Actions" could be placed in the executive summary to assist the decision makers. This adjustment would be fairly minor because the HCM designers already address problem areas in some of their applications (see the HARDMAN SINCGARS application) (28).

i. Suggested Corrective Action for Projecting Manpower Out to System Deployment. Examples of manpower regression models were provided earlier in Section V. The key problem identified with these models was the lack of any indication of uncertainty in the manpower availability projections. Nevertheless, it is extremely important to compare the projected manpower requirement against manpower available starting at the point of system deployment. A simple initial approach to this dilemma might be to employ a linear regression technique, such as Barnes' Soldier 90, and allow an end point spread representative of only 75 or 80% confidence (i.e., select a confidence interval low enough to prevent too large a spread at the projected system deployment time) (43). The final projection may appear as shown in Figure 7-2, where the shaded area might represent the zone of confidence in which 75 or 80% of the observed data points center around the least squares projection (43).

If the projected manpower requirement resulted in the situation depicted in Figure 7-2, then obviously there is potential for a critical manpower shortage. However, if the projected requirement fell within the shaded area, then for purposes of early planning, it would appear that there

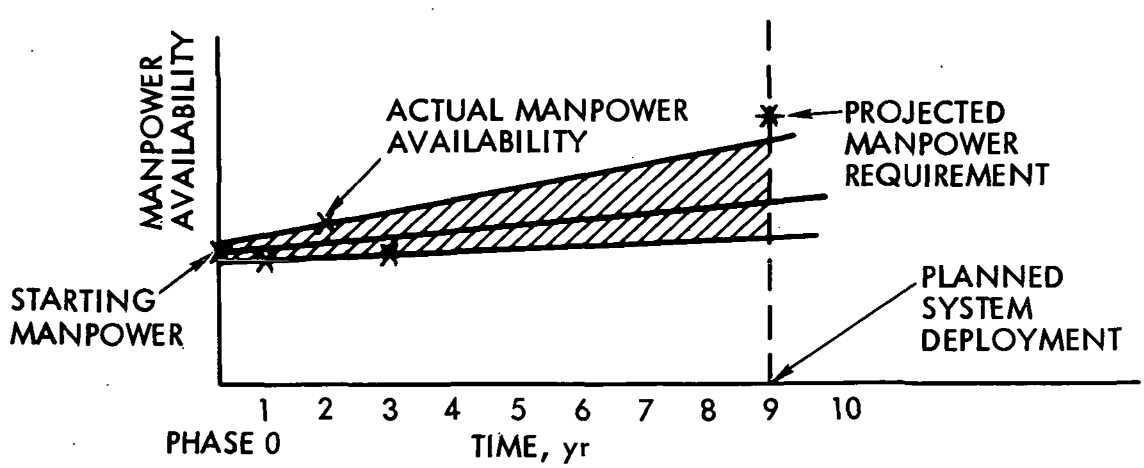


Figure 7-2. Use of Confidence Intervals for Manpower Projections

was no immediate problem. The advantage of this approach is that the projection can be made with greater confidence as the deployment date is approached and more data points on manpower availability are obtained. Probably the actual confidence in the projection would not have to be any better than one minus the allowable error on the manpower projection (i.e., roughly 0.8, as determined in Section VI).

j. Suggested Corrective Action for Improving LCC Tradeoff Analysis. As shown earlier in Section V, some life-cycle cost elements are already included in the HCM. One of many typical life-cycle cost models was also briefly summarized (i.e., HLCCM). It is merely suggested here that other life-cycle cost models be reviewed and the remaining missing cost parameters be incorporated in the methodology to form a complete cost and impacts assessment.

k. Suggested Corrective Actions to Firm Up Perturbation, Induced Failure, and Indirect Productivity Value Ranges. The 20% upper bound on the expected performance and reliability improvement of new technology was discussed earlier in this section. This expected improvement, however, is only one part of the complete picture. The previous discussion also pointed out the possibility that a different operating scenario or harsher environment could drive the reliability of a new design below that of its predecessor. At a top level it was merely suggested that the final manpower projection be stated as "greater than X number of people." The next step would be to try to establish an approximate estimate of the potential drop in reliability. A threefold approach is suggested to obtain this estimate:

(1) Studies such as the earlier referenced Dobbins paper suggest roughly an order of magnitude difference between contractor estimates of reliability and actual field operation (42). It may be enlightening first to determine the components involved in the above Dobbins reliability tests, choose equivalent predecessor components, compare the operating environments in terms of relative harshness, and calculate the incremental difference between the respective reliabilities to get an idea of whether new technology (operating in a different environment and adjusted to its realistic performance level according to Dobbins) experiences a reduction in reliability below its predecessor.

(2) As a next step it may be useful to conduct a survey of program managers in all four services to gather examples (and maintenance data) of systems and components where the reliabilities fell far short of their original goals. Again, establish the equivalent predecessors that were replaced by those new designs, compare the harshness of the operating environments, and calculate the incremental difference in reliability between the two. Several different kinds of components should be examined to determine which technologies are more sensitive than others (i.e., computers, propulsion components, firing devices, etc.).

(3) Finally, establish a group of experts from various technical fields in DOD to adjust the estimates considering that research and development programs provide engineering fixes that allow some of the reliability to be regained before a fairly steady-state reliability level is reached.

The induced failure and indirect productivity variables can effect the outcome of the manpower projection even though their ranges are not as broad as the perturbation value. As a first step it is suggested that a sensitivity analysis be conducted, using completed HARDMAN applications, by simply calculating the spread in manpower for the complete ranges of both variables. If the spread does not aggravate the sensitivity of the manpower variable, then a single, perhaps mid-point, value should be selected to remove any confusion in picking a value from the possible ranges. If the spread exceeds the allowable error, then more detailed breakdowns using industry and services industrial engineering studies (for indirect productivity factors) or the Navy 200,000 Hour Test Study (for human induced failure rates) will have to be used (41).

2. Training of HARDMAN Analysts

One of the major results of the audits and reliability analyses was that the methodology appeared usable by only a select group of individuals. Comments made during the debriefing following the internal validity test universally suggested that no <u>one</u> individual could exercise the methodology reliably; a team effort was absolutely required. It was discovered that the net expertise required was a combination of the following:

(1) Sufficient military experience to provide both an understanding of where to obtain training and technical information, as well as the structure of the military logistics support, personnel and training environments.

(2) Technical capability in at least one of a wide range of technical fields encompassing mathematics (particularly modeling), behavioral sciences, aerospace engineering, mechanical engineering, electrical engineering, and chemical engineering.

(3) Experience in computer information and data management systems.

(4) Experience with DOD personnel assignment and tracking processes.

Again, based on comments made by replication analysts during the debriefing and discrepancies review (41), it seems that the most suitable combination of the above abilities was either items (1), (2), and (3), or items (1), (2), and (4). Note that the joint military and technical experience recur in both combinations. The personnel experience could be an extension of the military experience; and, similarly, the computer information system experience could greatly enhance the technical experience. All of these attributes exist to varying degrees in the individuals employed by the HCM contractor who execute the HARDMAN methodology (31). While some of the first-year methodology design recommendations are being explored, the Army

might consider using these qualifications to select and staff its HARDMAN analyst team(s). In preparation for possibly conducting in-house applications of the methodology or managing and auditing contractor applications, it is extremely important that the Army firm up the various judgment areas per the preceding recommendations. This effort will also provide for a clearer training foundation. Drawing on both the results of the preceding evaluation and debriefing comments, the following training suggestions are provided:

(1) The original objective of the HARDMAN training session (in preparation for the internal validity test) was to concentrate on developing skills for the judgmental portions of the methodology. This objective should remain the major training thrust because the algorithms and number manipulation are fairly straightforward. Comments made on the debriefing questionnaire suggest that the first training session concentrated too heavily on the numbers and data manipulation.

(2) The handouts (particularly the LSA data and examples) should be designed and their presentation associated more clearly with each step and judgment in the process. The emphasis should be placed on defining the judgment process and, where calculations are required, concentrate on only a few select cases that demonstrate the possible range of judgments that may be encountered. Note that the suggested corrective actions made earlier in this section could help refine the judgment process and that some of the peculiar data management, reference system construction, and credibility problems discussed earlier as part of the SINCGARS, RPV, and DSWS audits could be employed as example problems.

(3) Break down the process by areas of expertise and provide different focuses for the backgrounds of various individuals (i.e., teach the team approach and define participant responsibilities).

(4) Train for the complete six-step methodology (e.g., as part of the training program it may be useful to have the Army analysts work as apprentices at the HCM contractor's facility as a means of obtaining experience).

These recommendations should not be construed as only applying to HARDMAN analysts. Even if the Army only chooses to monitor contractors performing applications in response to a Data Item Description (DID) in a contract, it is still imperative that contract monitors have the recommended training to ensure quality control of the outcomes and answer ASARC or Program Office audit requests.

3. Suggestions for Follow-on Research

There were four far-term areas identified earlier in this section. These areas revolved around consideration of emerging systems (horizontal analysis), quantitative differentiation between critical and non-critical tasks, expansion of the demographic data base, and consideration of major socioeconomic fluctuations. Except for horizontal analysis, the

remaining areas are probably not critical to early Phase 0 and Phase I top-level budget planning. As a first step, it is suggested that the Army initiate appropriate directives to require early planning of "most likely" candidates to be approved as emerging systems, inclusive of early operational and projected logistics support data. It is recognized that this is a large and perhaps sketchy task. However, if the Army wishes to meet its user needs and consider major drains of other systems on the personnel pool, it must start the mechanism to gather the needed information as soon as possible.

The three remaining areas are considered far-term because they represent large data-gathering activities. For example, the quantitative critical and non-critical task differentiation effort might be accomplished by (1) first establishing criteria for critical and non-critical tasks (e.g., life or mission endangering, task difficulty); (2) selecting an array of systems representative of obvious task extremes for operator or maintainer performance (e.g., aircraft pilot versus an RPV operator); (3) calculating the ratios of instructor hours for the extremes; and (4) developing a simple rule of thumb to increase instructor contact hours by "X" percent in Step 3 of the methodology for those tasks judged critical. The time-consuming aspect of an effort such as this is the task sorting and rating study associated with item (1) followed by the gathering of system examples and instructor task hours associated with items (2) and (3). It is for these reasons that the "obvious task extreme" qualifier was suggested as a starting point.

The completion of the demographic data base is a massive effort because it not only involves the gathering of data on age, sex, education, etc., but also requires expansion of the decision network in Step 2 of the HCM (i.e., skill and MOS assignments). It may be worthwhile for the near and intermediate terms not only to require manufacturers contractually to adher strictly to accepted human engineering guidelines but also to establish a design auditing mechanism to ensure strict compliance with <u>sound</u> human engineering standards.

The last area, socioeconomic impacts on manpower, should be pursued in the manner expressed by Enke earlier in the document. In the interim, a subjective weighting mechanism might be employed to indicate the general direction of manpower trends (up or down), based on expert experience with the various variables (such as the economy). Referring back to the earlier recommendation on the use of confidence intervals around the long-term manpower availability projection, the final manpower projection might simply indicate that the most likely availability population would be either above or below the least squares linear projection, depending on the historical effect of the socioeconomic variables.

The final far-term research area refers to one of the original constraints imposed on this evaluation. Due to time and budget constraints, only a qualitative examination of methodology accuracy was feasible. It is strongly suggested that a feedback loop be constructed so that actual field data on completed applications are gathered as the new systems are deployed. If the actual system MPT performance falls outside the allowable error discussed in Section VI, then appropriate steps should be taken to backtrack through the studies and strengthen those weak areas in the methodology.

In conclusion, several different validity examinations were structured to evaluate the HCM. Table 7-1 indicates that the technique was generally sound and basically integrated all aspects of the MPT problem well. Although some weaknesses were discovered, solutions (or solution structures) were apparent in most cases and appeared attainable within a reasonable time period. If the Army chooses to pursue the proposed recommendations, several benefits might be realized:

(1) The Army will move closer to developing its own in-house HARDMAN capability (if it elects to do so).

(2) The Army will improve the audit trail on MPT projections.

(3) The Army will have a sound tool for producing MPT requirements, weighing the credibility of projections, and making better personnel recruitment and budget decisions in the manpower support arena.

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APPENDIX A

INTERVIEW QUESTIONS FOR USER REQUIREMENTS

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USER REQUIREMENTS
QUESTIONNAIRE

1. To what organizational division of the Army do you belong?
VERBATIM

2. What is the primary charter of your organization?
VERBATIM

3. What are your specific duties within the organization?
RESPONSIBILITY: (Areas of Concern, Deliverables, etc.)

4. What are your key needs in making or using manpower personnel and training projections (i.e., what do you need to have to do this?)
INPUTS: Type of data, Level of Detail

INTERFACE CONSIDERATIONS
Other Organizational Actors (input/output)

Timing

5. What are the key drivers in needing such MPT projections, e.g., cost, planning, safety, performance, readiness/force modernization, etc?
SPECIFY AND EXPLAIN, if possible

6. Which ARMY MPT regulations/documents pertain to your organization's involvement in the M.P.T. process?

7. What technique is presently employed for getting MPT inputs into system acquisition process?

8. Who has responsbility for this technique?

9. To your knowledge, does it provide good results?
SPECIFY

10. In your organization, who is (are) the most likely user(s) of a methodology to make MPT projections?

11. What other users of the the methodology could you identify within the Army organizational structure?

12. Who in your organization is (are) the most likely user(s) of the results of such a methodology?

13. What other users of the results of such a methodology could you identify within the Army?

14. What suggestions do you have for the design of a methodology to accomplish MPT projections? (OUTPUTS, SCHEDULE, PROCESS, ETC.)

15. What would be the most useful format(s) for the results?

16. At what point in the acquisition process (i.e. Phase O, I, etc.) do you require MPT results for (a) design changes, or (b) cost control?

APPENDIX B

USER REQUIREMENTS SUMMARY
MATRIX OF QUESTIONNAIRE RESPONSES

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HARDMAN USER REQUIREMENTS SUMMARY MATRIX (DESIGN)

USERS	DARCOM (I)	DARCOM (II)	SSC-NCR -TRADOC- (I)	SSC-NCR -TRADOC- (II)	SSC-NCR TRADOC (III)	DCST HQ, TRADOC	DCSCD HQ, TRADOC	SSG-TSM -TRADOC-	LOGCEN -TRADOC-	DEVICES AND SYSTEMS TRAINING DIRECTORATE DCST, TRADOC	LOGISTICS EVALUATION AGENCY (LEA) -DCS LOG-	DCS PER MANPOWER, PROGRAMS, AND BUDGET	INDUSTRY
REQUIREMENTS (DESIGN)	ILS MANAGER	ILS MANAGER	DIR. SOLDIER INTEGRATIONS	FROM DOCUMENTS DIR SOD DEP COR SSC-NCR	CHIEF ECA/HARDMAN TASK FORCE	TRAINING DEVELOPER	COMBAT DEVELOPER	TRADOC SYSTEMS MGR	MAT'L SYSTEMS TRAINING FORCE DEVELOPMENT	ARMY TRAINING SUPPORT CENTER	INDEPENDENT LOGISTICIAN	FORCE MODERNIZATION CELL	FROM SURVEY DOCUMENT
1- MPT PROJECTIONS NEEDED <u>BEFORE</u> MILESTONE I OF SYSTEMS ACQUISITION CYCLE FOR MAXIMUM DESIGN INFLUENCE AND COST CONTROL	X	X	X	X	X	X	X	X	X	X	X	X	X
2- MPT DATA SHOULD BE PROVIDED THROUGHOUT A SYSTEM'S LIFE CYCLE	X	X	X		X	X	X						
3- DATA SHOULD BE DEVELOPED FOR SYSTEM ALTERNATIVES (PROPOSED), AS WELL AS PREDECESSOR SYSTEM FOR COST COMPARISONS		X	X										
4- FEEDBACK MECHANISMS SHOULD BE INCORPORATED TO PERMIT DEVELOPMENT OF HISTORICAL DATA BASE WITH UPDATE CAPABILITY	X	X	X			X					X	X	
5- SYSTEM SHOULD BASE CALCULATIONS ON RELIABLE DATA SOURCES AND DOCUMENT THESE SOURCES FOR CREDIBILITY	X	X	X		X			X				X	
6- LSA DATA SHOULD BE UTILIZED AND PRODUCED IN LSA FORMATS FOR EASY RECOGNITION/USE		X							X	X	X		
7- MPT MODEL SHOULD EXPOSE ASSUMPTIONS AND LIMITATIONS WHICH DISTINGUISH PROPOSED FROM CURRENT SYSTEM DATA				X							X		
8- MANAGEMENT INFORMATION SYSTEM SHOULD FOCUS ON "FIRST UNIT EQUIPPED," INCLUDING SPACES, FACES, AND EQUIPMENT DATA							X					X	
9- MPT MODEL SHOULD BE TARGETED TO BOTH BUDGETARY AND SYSTEM MILESTONES ON A TIMELINE WHICH INCLUDES ACTION–SIGNALLING MECHANISMS AND SPECIFICATION OF RESPONSIBLE PARTIES						X	X			X		X	
10- PERMANENT, CENTRALIZED ARCHIVING CAPABILITY (HARDCOPY AND DISK STORAGE) IS ESSENTIAL FOR ACCESS/AUDIT/REVIEW/UPDATE							X						X
11- FRONT-END COST/BENEFIT CRITERIA SHOULD BE APPLIED BEFORE SELECTING SYSTEM FOR MPT ANALYSIS (BASED ON TECHNOLOGY CHANGES)											X		
12- MPT MODEL SHOULD IDENTIFY SUPPORT SYSTEM(S) OR OTHER SYSTEMS WITH OVERLAPPING OBJECTIVES IN PROVIDING COMPREHENSIVE MPT ANALYSIS	X					X							X
13- MPT DOCUMENTATION FORMATS/REPORTS SHOULD BE COMPATIBLE WITH THOSE USED TO INFLUENCE TRADOC MOS DECISIONS	X		X	X	X	X	X	X	X			X	
14- MPT DOCUMENTATION SHOULD PROVIDE DCS PER WITH COMPARATIVE MANPOWER REQUIREMENTS FOR SYSTEM ALTERNATIVES/PREDECESSORS	X	X	X		X	X	X	X				X	
15- DOCUMENTATION MUST BE AVAILABLE FROM DCS PER AT FRONT END RE: AVAILABILITY OF PERSONNEL FOR EACH MOS/SKILL LEVEL ASSOCIATED WITH SYSTEM		X				X		X		X			
16- TIMELY/ACCURATE DATA MUST BE GIVEN TO CONTRACTORS TO PREPARE RFP'S AND/OR ORGANIZATIONAL MAINTENANCE MANUALS		X											X
17- IMPROVED VEHICLE FOR MPT INFORMATION EXCHANGE <u>MANDATORY</u> TO PERMIT EFFECTIVE/TIMELY COMMUNICATION (SYSTEM SHOULD BE INTERACTIVE)	X	X			X	X	X					X	X
18- MPT MODEL MUST MEET MULTIPLE USER'S NEEDS FOR OPERATIONAL FEASIBILITY & INTEGRATION INTO, AND/OR IMPLEMENTATION IN THE ARMY THROUGH EXISTING REPORTING STRUCTURES			X		X	X	X					X	

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HARDMAN USER REQUIREMENTS SUMMARY MATRIX (OUTPUT)

USERS	DARCOM (I)	DARCOM (II)	SSC-NCR -TRADOC- (I)	SSC-NCR -TRADOC- (II)	SSC-NCR -TRADOC- (III)	DCST -HQ. TRADOC-	DCSCD -HQ. TRADOC-	SSC-TSM -TRADOC-	LOGCEN -TRADOC-	DEVICES AND SYSTEMS TRAINING DIRECTORATE DCST, TRADOC	LOGISTICS EVALUATION AGENCY (LEA) -DCS LOG-	DCS PER MANPOWER, PROGRAMS, AND BUDGET	INDUSTRY
REQUIREMENTS (OUTPUT)	ILS MANAGER	ILS MANAGER	DIR. SOLDIER INTEGRATIONS	FROM DOCUMENTS DIR SOD DEP CDR SSC-NCR	CHIEF ECA/HARDMAN TASK FORCE	TRAINING DEVELOPER	COMBAT DEVELOPER	TRADOC SYSTEMS MGR	MAT'L SYSTEMS FORCE DEVELOPMENT TRAINING	ARMY TRAINING SUPPORT CENTER	INDEPENDENT LOGISTICIAN	FORCE MODERNIZATION CELL	FROM SURVEY DOCUMENT
1- OPERATOR/MAINTAINER TASK DATA ASSOCIATED WITH A SYSTEM AND ITS SUPPORT/TEST EQUIPMENT (DESCRIPTION AND FREQUENCIES)	X	X	X	X	X	X	X	X	X	X	X	X	X
2- MAINTENANCE MANHOURS/MANPOWER DEMAND BASED ON ACCURATE RAM DATA	X	X	X	X	X	X	X	X	X	X	X	X	
3- MOS, SKILL LEVEL REQUIREMENTS, ADDITIONAL SKILL INDICATORS (ASI), AND TOTAL NUMBERS OF SPACES (PERSONNEL REQUIREMENTS)	X	X	X	X	X	X	X	X	X	X	X	X	X
4- MAINTENANCE CONCEPT, INCLUDING MAINTENANCE LEVELS, MTTR, MTBF	X	X	X	X	X	X			X		X		X
5- COMPREHENSIVE TRAINING CONCEPT -CLASSES REQUIRED (UNIT/INDIV./INSTITUTIONAL) -TRAINING TIME, FREQUENCY -QUANTITATIVE AND QUALITATIVE TRAINING INCREASES -TRAINING SUPPORT (DEVICES, INSTRUCTORS, FACILITIES)	X	X	X X X X X	X X X	X X X X	X X X X	X X X	X	X	X X X X X	X X	X X	
6- PERSONNEL AVAILABILITY/CONSTRAINTS PERSONNEL PROJECTIONS, TRENDS		X	X X		X X	X X	X X	X X		X	X X	X X	
7- MPT COSTS ASSOCIATED WITH SYSTEM OPERATION AND SUPPORT	X	X	X	X	X	X	X	X	X	X			
8- TRADEOFFS BETWEEN HARDWARE AND PEOPLE		X	X	X	X	X	X	X	X		X	X	X
9- ACCURATE LSA DATA BASED ON COMPARISON TO REPLACED SYSTEM	X	X	X	X		X			X				X
10- HISTORICAL DATA BASE (UPDATE CAPABILITY)			X				X		X			X	X
11- MPT PROJECTIONS BASED ON MISSION OR SCENARIO-DRIVEN USAGE RATES/PROFILES						X		X	X				X
12- HORIZONTAL (TOTAL SYSTEMS) IMPACT OF MPT SUPPORT/LOGISTICS	X	X	X		X	X	X	X	X	X	X	X	X
13- MPT "DATA SLICE" REPRESENTATIVE OF BASIC UNIT OF DEPLOYMENT (AN EQUIPPED UNIT, SUCH AS A BATTALION, COMPANY, ETC.) ISS*				X			X		X	X			
14- TARGET AUDIENCE DESCRIPTION -READING AND GRADE LEVELS -EXPERIENCE -SKILLS (TASKS ALREADY TRAINED...) -DEMOGRAPHICS			X X			X X X X	X X X X	X X X X	X X X X	X X X X	X	X X X X	X X X X X
15- COMPREHENSIVE DATA BASE OF TASK FILES, USING: SOLDIER'S MANUAL (SM); ARTEP; PROGRAM OF INSTRUCTION (POI); SKILL QUALIFICATIONS TESTS (SQT); TRAINING GUIDE (TG); AND ENLISTED CAREER MANAGEMENT FIELDS & MOS (AR611-201)		X	X					X	X				
16- MOS "ALIGNMENT" DATA RE: CURRENT MOS STATUS; AUTHORIZATION VS. REQUIREMENTS			X	X			X	X		X		X	
17- THREAT BASE INFORMATION													X
18- DETAILED OPERATIONAL AND ORGANIZATIONAL (O&O) CONCEPT FOR THE SYSTEM INCLUDING TOE DATA								X					X
19- MATURE LSA DATA FROM FIELDED SYSTEMS TO VERIFY INFORMATION SYSTEM AND PERMIT ANALYSIS OF SYSTEM SUPPORT		X	X			X	X				X		
20- SIMPLE FORMATS, INCLUDING CHARTS, TABLES, GRAPHS		X	X		X	X							
21- PRECISE TASK BREAKDOWN FOR EACH MOS ASSOCIATED WITH A SYSTEM		X	X						X	X	X		
22- HARDCOPY AND CRT DISPLAY CAPABILITY (PERMANENT ARCHIVING)							X						
23- EXECUTIVE SUMMARY REPORT TO ACCOMPANY OUTPUTS					X								
24- OUTPUT SHOULD BE DATA NEEDED IN LETTER OF AGREEMENT (SEE 13)						X	X		X				

*REFLECTS INTEGRATED SYSTEM SUPPORT (ISS) FOCUS.

APPENDIX C

AUDIT QUESTIONS

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METHODOLOGY AUDIT

Generic

Steps 1 and 2

1. What judgment determines the level of indenture necessary in determining the functional requirements?

2. How does one determine the maturity of the data presented? How does on ensure selecting the most mature data source(s)?

3. The judgments used to determine manpower drivers in the design difference index are not clear to me:

   How are the key drivers flagged?
   How is the perturbation value assigned?
   When and where is the perturbation value applied?

4. What judgment is required and how is it applied to select the lowest skill level MOS for any maintenance task when the AR611-201 seems to define the performance of each MOS quite clearly?

5. What judgments temper the use of the indirect productivity factor? Is this a blanket application or a selected application? Define why and when.

6. What judgments allow the incorporation of two tasks, normally performed by two separate MOS's, into one MOS?

7. What judgments are used in creating a new MOS?

8. When and where are the perturbation values applied to the reference system to achieve a baseline system with which to compare the contractor-proposed data?

9. Is the function to address the manpower loading a rectangular or weible curve?

10. How is the accuracy of the reference system ensured when contractor-proposed data is used in building a reference system component for which no predecessor data is available?

11. How do you construct a reference system to be similar to the proposed system when the proposed systems vary widely?

12. Does the HARDMAN Methodology take into account factors other than those addressed by the contractor? Are the DRC reference system manpower requirements more credible than the contractor-proposed requirements?

METHODOLOGY AUDIT

Generic

Step 3

1. Is the training necessary for the instructors taken into account? Training for the instructor's instructors?

2. Are the costs of training the instructors taken into account? The costs of training the instructor's instructors?

3. What judgments are used in identifying and constructing training courses for any new ratings developed?

4. When the technical factors for determining the baseline skill levels are analyzed, is memory decay taken into account?

5. Explain the two levels of indenture for determining training requirements; the Methodology seems to address only the first.

6. What determines the frequency or need for refresher (retraining) courses?

7. How does the TRRA estimate the cost of devices required for training?

8. Are the costs for personnel movement between training schools and training periods included in training costs? Are these large costs?

9. How often is it required to send personnel back through the training schools? Is this a large cost?

10. How are the perturbation values determined in steps 1 and 2 applied to the reference system training courses?

METHODOLOGY AUDIT

Generic

Step 4

1. How are the personnel required for new MOS's accounted for?

2. Where is the flow of second enlistment personnel taken into account?

3. How is a personnel flow conducted for a new MOS when no historical data is available?

4. Where do the probabilities to calculate the flow of personnel come from? How are they applied to the MOS populations to establish the expected values of availability?

5. Are major socioeconomic fluctuations considered?

6. Is a steady-state population within the Army assumed?

7. How are the perturbation values determined in steps 1 and 2 applied to the reference system personnel requirements?

Conclusions

1. Why is a Life Cycle Costing (LCC) model not included in the Methodology?

2. When, if at all, is a wartime scenario addressed?

3. How much credibility is lent to the results of the analysis?

METHODOLOGY AUDIT

DSWS/RPV-Specific

Steps 1 and 2

DSWS

1. What justification does PACCAR have for utilizing an "M-2-like" chassis in a potential overload situation?

2. What accounts for the vast differences in manpower between the Norden M109E4 system and the reference and other proposed systems?

3. Why weren't personnel and training analyses performed on the PACCAR system?

4. The Norden M109E4 system has no Ammunition Resupply Vehicle (ARV). The PACCAR system uses only one ARV per two Howitzers. How do these two systems get considerations as proposed systems if the functional requirements were developed properly? Do you consider the fact that the PACCAR system uses one ARV per two Howtizers a potential error source?

5. Why was a shipboard gun autoloader chosen for the reference system?

6. For the following subsystems, what judgments were used in determining the design differences? What judgments were used in assigning a perturbation value? How were these values applied to the reliability and maintainability data? How did they affect the manpower projections for the reference system?

    a. Autoloader
    b. Fire Control Processor
    c. Internal Navigation System
    d. Auxiliary Power Unit
    e. Suspension: 1. Howitzer
       2. ARV (where applicable)
    f. Howitzer Engine
    g. Suspension/Chassis Combination

7. In building the reference system, what criterion were used to determine the maturity of the data?

8. How does the use of a trailer with the FMC system affect the reliability and maintainability of that system? How does the use of a trailer affect the munitions-loading capabilities of that system?

9. What accounts for the vast differences in manpower projections between the reference and proposed systems in the following MOS categories: 31V, 31E, 35E, 63D.

10. What accounts for the extremely low number of the following MOS's in the Norden M109E4 system: 31V, 31E.

METHODOLOGY AUDIT

DSWS/RPV-Specific (cont'd.)

<u>Steps 1 and 2</u>

DSWS (cont'd.)

11. Why was an airborne unit selected as the reference navigation system?

12. What justification exists for Norden and FMC systems not using an Auxiliary Power Unit?

13. How was the M-1 tank Auxiliary Power Unit data altered to take into account its lack of predicted performance?

RPV

1. Track the source of the Mean-Time-To-Repair (MTTR) values of the reference system for the following subsystems:

   a. Data link terminal (airborne unit)
   b. Airframe assembly
   c. Launcher

2. Identify the reference equipment and selection rationale for the following subsystems:

   a. Central Processor Unit (CPU)
   b. RPV control and display panel
   c. Airframe assembly
   d. AV engine
   e. Launcher

3. Track the Contractor-Furnished Equipment data from the baseline system equipment that was used in the reference system for the following subsystems:

   a. Launcher
   b. CPU
   c. Airborne unit data terminal

4. Identify the subsystems of the baseline system that did not meet the functional requirements.

5. Identify the baseline equipment that used altered contractor data. Explain the rationale for altering this data.

Steps 1 and 2

RPV (cont'd.)

6. Identify and provide the rationale for the perturbation values (PV) assigned to the following subsystems:

   a. Airborne unit data terminal
   b. CPU
   c. AV airframe
   d. AV engine

   If no PV was used in the above subsystems, identify where the PV was used.

7. Identify baseline equipment where no reliability and maintainability (R&M) data was available.

8. Track MOS/Skill level assignments for the following subsystems:

   a. Airborne unit data terminal
   b. CPU
   c. Airframe assembly
   d. AV engine

9. Page 48 of Volume 1, RPV states that the assumption is made that the MAC charts exclude the make-ready/put-away times, a value which would normally be adjusted by the Indirect Productivity Factor. In the SINCGARS replication, the instructions stated that the make-ready/put-away times were included in the MAC chart data. Explain this discrepancy.

10. Explain how full-sized aircraft data was altered in order to meet miniaturized aircraft data projections.

11. Page 75 of Volume 1, RPV makes reference to certain modeling equations. Explain these.

12. What is the basis for a two-to-one improvement of the M939 truck over the M809?

13. What criterion are used in determining the number of systems to be fielded? Are these criterion adjusted for system availability?

Step 3

DSWS

1. How did the perturbation values assigned to components of the following subsystems of the reference system affect the training resources requirements analysis?

   a. Autoloader
   b. Fire Control Processor
   c. Internal Navigation System
   d. Auxiliary Power Unit
   e. Suspension: 1. Howitzer
      2. ARV (where applicable)
   f. Howitzer Engine
   g. Suspension/Chassis Combination

2. What training impacts are effected by the use of a trailer in the FMC system?

RPV: For Questions 1 and 2
References: RPV Appendix C - pp. 3, 4, 27, 30, 57
Subsystems: Air Vehicle, airborne data terminal, remote ground terminal

1. What was the rationale for assigning the PV's? What are the values that were arrived at?

2. What is the rationale for choosing the respective representative equipments for training estimation? What would the procedure be if a detailed Training Resources Requirements Analysis (TRRA) was conducted?

3. Identify the nine new courses in the reference system; the seven modified courses in the baseline system; the two deleted courses in the baseline system.

4. Discuss the implications of the fact that, in many cases, Direct Support (DS) level maintenance was not specified in the Logistics Support Analysis (LSA) data.

5. Discuss the low performance that may result from high skill requirements and low paygrade assignments as indicated on page 119, RPV; explain why this was not identified in the recommendations; how was this addressed in the reference system?

Step 3 (cont'd.)

RPV: (cont'd.)

6. Explain, by example, the four steps in determining the number of instructors for one course.

7. Show an example of a Program Of Instruction (POI) used for obtaining training man-days.

8. Since the HARDMAN Methodology does not address Life Cycle Costing (LCC), and only addresses a potion of the training costs, why address it at all? Why wasn't it addressed in RPV?

9. In general, how does this step interrelate with the MOS/ASI selection in step 1?

Step 4

DSWS

1. How did the perturbation values assigned to components of the following subsystems of the reference system affect the personnel requirements?

    a. Autoloader
    b. Fire Control Processor
    c. Internal Navigation System
    d. Auxiliary Power Unit
    e. Suspension: 1. Howitzer
                   2. ARV (where applicable)
    f. Howitzer Engine
    g. Suspension/Chassis Combination

2. What personnel requirements are affected by the use of a trailer in the FMC system?

RPV

1. Does the primary output of this step, personnel to be trained per year, represent requirements at IOC, 5 yrs., 10 yrs., . . . ?

2. Discuss the sources of personnel flow rates. Why does DRC rely on Army data and not develop its own models, or use the algorithms outlined in the HARDMAN Methodology handbook? What is the expected error in the primary output due to inadequate data inputs?

3. Explain, by example, personnel flow in the 13T MOS structure.

4. Are there other Army data sources available, such as TRADOC?

Step 5

RPV

1. Page 154, RPV states that meaningful results can be obtained in the case of RPV since it is a completely new system. Does this imply that meaningful results could not be obtained if this were not the case?

2. Does DRC provide inputs or actually run the Army's Personnel Policy Project Model (P^3M)?

3. The P^3M Model projects personnel suply based on Army internal variables; what of external variables such as the economy or politics?

4. Are the P^3M personnel inputs different from those used by DRC in step 4 of the Methodology?

5. Given the short horizon, one to three years, of the P^3M Model, is there a better way and why?

6. How do authorizations relate to the TO&E?

Step 6

RPV

1. How long does it take to conduct a tradeoff study?

2. Discuss, by example, the tradeoff study of the M939 truck versus the ML809 truck.

Conclusion

1. What conclusion can you draw from the chart on page 5, RPV; what conclusions can we draw on how credible the answers are?

APPENDIX D

DEBRIEFING QUESTIONNAIRE

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TRAINEE DATA COLLECTION SHEET

HARDMAN PROJECT

In order to analyze and identify possible explanations for divergence in trainee's solutions to problems worked during the training course, we need to determine the following background data on each person.

1. TRAINEE I.D. # (NAME)

2. LEVEL OF EDUCATION

   NO. YEARS COMPLETED ______________________
   ADVANCED DEGREES? ______________________
   CERTIFICATES? ______________________
   COLLEGE DEGREE ______________________
   HIGH SCHOOL ______________________

3. TYPE OF EDUCATION

   ADVANCED DEGREE FIELD(S) ______________________
   COLLEGE MAJOR ______________________
   H.S. EMPHASIS ______________________
   - COLLEGE PREP ______________________
   - TECHNICAL ______________________
   - VOCATIONAL ______________________
   - OTHER ______________________

4. PRESENT EMPLOYMENT

   TITLE:

   EMPLOYER:

   DUTIES:

   LENGTH OF TIME (IF ANY) AWAY FROM PAST EDUCATION FIELD OF EMPHASIS (MAJOR, FIELD, ETC.)

5. PAST EMPLOYMENT

   IN REVERSE CHRONOLOGICAL ORDER, PLEASE LIST RECENT JOB EXPERIENCE (UP TO 5 YEARS)

DEBRIEFING QUESTIONS

1. Did you complete all 8 sections of the replication package?

   If NO, state which portion is incomplete...

2. Were the recommended time frames realistic?

   If NO, state specific packages which took more/less time than recommended.

3. Was the subject material or methodology of this replication process directly or indirectly related to your present job?

   If YES, state how (briefly)

4. Were there portions of the replication that you felt were particularly difficult? (Beginning with package 1, please give any significant notations you made about the package while working on the replication. Please omit problems which were readily resolved by a telephone call of DRC. Also include comments about possible reasons and solutions for the problem.)
Prompts: Complexity; Course training; Time factors, e.g., lag between course & replication or time to finish package; Materiels, Preparation of individual..)

5. How did you generally make corrections to your answer sheets on the RT Unit and the ECCM?

Prompts: Straight DRC worksheet utilization; Mapping over of my answers to DRC worksheet or vice versa; Other.....; Special problems noted.

6. Were the instructions in the data packages generally adequate for interpreting what was actually required, i.e., calculating the required answers?

If NO, please explain possible reasons and state which data package.

7. Did you note any significant descrepancies between your solutions and the "school" (DRC) solutions during the replication?

If YES, please state reasons, if known. (Prompts: Replicator background; Training course; Data package instructions, materials; Other (errors,etc.)

8. What would have been required of you to arive at the school solution (DRC answers)? Apply comments to specific data packages.

9. Did you read the pre-replication patkage materiels for the SINCCARS?

If YES, were they useful?

10. Did the course prepare you adequately for the replication?

EXPLAIN...

11. What criteria could you suggest for selecting analyst trainees to apply HARDMAN? (Answer may vary for different steps in the process)

12. Do you have any suggestions for training course improvements?

APPENDIX E

DATA INPUTS FOR THE MANPOWER SENSITIVITY MODEL

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This appendix contains the data sets and baseline runs of the SEDCOM cost model. The first table is the baseline run used in the analysis. The equipment used there is SINCGARS without the battery. This was done because the battery, with extremely low mean time between failures, takes a long time to run on the computer and adds nothing to the analysis. For the sake of completeness a second baseline cost estimate is presented, based on the inclusion of the battery. It is labeled SNCGARS2.

Most of the input data used to describe both SINCGARS and its operating and support environments were provided by the SINCGARS Program Office and are presented in the next several tables. Because the computer program used for this example was derived from the Navy SECDOM model, the billet structure and some maintenance level terminology (for example, ship level is organizational level) were merely adopted to prevent reprogramming. The use of some Navy terminology and data did not affect the accuracy of the sensitivity study because this effort was conducted strictly as a top-level (order-of-magnitude) analysis.

SINCGARS

COST ELEMENTS ($'000)	
Life Cycle Cost	885323.0
System Unit Cost	11.1
INITIAL COSTS:	
Production	359265.0
Maint. Training	1251.2
Op. Training	80850.0
Misc. Manpower	0.0
Spares	2844.2
S+TE	67048.6
Tech. Doc.	55.2
**TOTAL	511314.0
OPERATION AND SUPPORT COSTS:	
Maint. Wage	31587.0
Op. + Off. Wage	35684.7
Maint. Training	3842.2
Op. Training	248394.0
Misc. Manpower	0.0
Spares	11018.2
Repair	2257.9
Transportation	20.2
S+TE	41198.5
Tech. Doc.	5.5
**TOTAL	374009.0

SYSTEM RATES	
Number of LRA Types	17
Number of LRA's	17
Confidence Against Stockout	.999
System MTBF	472.3 hrs.
System MTTR	3.0 hrs.
SUPPORT POLICY SUMMARIES:	
LRA's coded COD	0
LRA's coded MOD	9
LRA's coded local repair	4
LRA's coded discard	4
TRAINING BILLETS BY TYPE:	
Equipment Operators	32340
Org and Int Maint	476
Depot Technicians	6
REAL MANNING REQUIREMENTS:	
Org. and Int. Maint.	235.97
Depot Maintenance	4.92
Operators	8085.00

SNCGARS2

COST ELEMENTS ($'000)

Life Cycle Cost	1126040.0
System Unit Cost	11.2
INITIAL COSTS:	
Production	314545.0
Maint. Training	1618.7
Op. Training	70280.0
Misc. Manpower	0.0
Spares	54779.7
S+TE	67048.6
Tech. Doc.	55.2
**TOTAL	508327.0
OPERATION AND SUPPORT COSTS:	
Maint. Wage	39707.1
Op. + Off. Wage	31019.4
Maint. Training	4971.3
Op. Training	215920.0
Misc. Manpower	0.0
Spares	282912.0
Repair	1962.7
Transportation	17.6
S+TE	41198.5
Tech. Doc.	5.5
**TOTAL	617714.0

SYSTEM RATES

Number of LRA Types	18
Number of LRA's	18
Confidence Against Stockout	.000
System MTBF	22.8 hrs.
System MTTR	0.4 hrs.
SUPPORT POLICY SUMMARIES:	
LRA's coded COD	0
LRA's coded MOD	9
LRA's coded local repair	4
LRA's coded discard	5
TRAINING BILLETS BY TYPE:	
Equipment Operators	28112
Org and Int Maint	616
Depot Technicians	6
REAL MANNING REQUIREMENTS:	
Org. and Int. Maint.	296.63
Depot Maintenance	4.27
Operators	7028.00

```
File name: SINCGARS

********************* NAVY ENVIRONMENTAL AND COST FACTORS *********************
 0 Daily cost of C-school training ($/day/student)....................... 250
 1 Cost of A-school, maintenance technician ($/student).................... 0
 2 Cost of A-school, operator ($/student).................................. 0
 3 Annual billet cost, maintenance technician........................... 30583
 4 Annual billet cost, operator......................................... 28235
 5 Annual billet cost, maintenance technician at depot.................. 38018
 6 Annual billet cost, officer............................................. 0
 7 Available weekly work hours, maintenance technician.................... 48
 8 Available weekly work hours, operator.................................. 60
 9 Available weekly work hours, depot technician.......................... 40
10 Annual turnover rate, shipboard personnel (decimal).................... .5
11 Annual turnover rate, depot personnel (decimal)....................... .33
12 Annual discount rate (decimal)......................................... .1
13 Condemnation rate (decimal)........................................... .01
14 S+TE support cost : S+TE purchase cost (ratio)......................... .1
15 Cost of technical documentation development ($/page).................. 200
16 Annual tech. documentation maintenance rate ($/page/yr)................ 20
17 Cost of insured freight ($/lb/mile)................................. .0002


************************* SYSTEM OPERATING ENVIRONMENT *************************
 0 Number of ships on which system is deployed............................ 28
 1 Number of systems per ship........................................... 1004
 2 Length of system life cycle (yrs)...................................... 10
 3 Length of deployment period (days)...................................... 5
 4 Number of deployments per year......................................... 52
 5 Average system operating hours (hr/wk)................................. 15
 6 Peak system operating hours (hr/wk).................................... 30
 7 Reduction rate (learning curve slope)................................... 1
 8 Number of stockage depots............................................... 3
 9 Number of repair depots................................................. 2
10 Cost of LRA repair at contractor depot............................... 1000
11 Ship response time (days)............................................... 2
12 Military depot response time (days).................................... 16
13 Contractor operated depot response time (days)......................... 20
14 Distance between repair and supply depots (miles)..................... 750
15 Other personnel costs ($/person)........................................ 0


*************************** SYSTEM DESIGN PARAMETERS ***************************
 1 Required system confidence level against stockout..................... .95
 2 System assembly cost at given lot size............................... 5204
 3 Lot size for assembly................................................. 100
 4 Average LRA weight (lb)............................................... 1.5
 5 Fault isolation hardware cost ($/system)....................... 2.35714E+06
 6 Support and test hardware cost ($/system)............................... 0
 7 Support and test software development cost.............................. 0
 8 Average LRA specific software development cost...................... 80000
 9 Technical documentation for system description (pages).................. 3
10 Technical documentation for fault isolation (pages)..................... 0
11 System scheduled maintenance requirement (manhr/wk/ship)............... .25
12 Required number of operators per system................................. 1
13 Required no. officers per platform...................................... 0
14 Required days C-school for operator training........................... 10
15 Required days C-school maintenance trng (sys orien + LRA R&R).......... 10
```

LRA Configuration for SINCGARS

CHASSIS: 1

0	Estimated unit cost	1400
1	Corresponding lot size	100
2	LRA mean time between failures (hours)	14006
3	Mean time to fault isolate, R & R this LRA (hours)	3
4	Mean time to repair LRA (hours)	1
5	LRA duty cycle (decimal)	1
6	LRA specific support and test hardware cost	67
7	Training hours required for repair of LRA	1
8	LRA repair material cost per failure	20
9	Pages of documentation for repair description	21
10	Quantity of similar assemblies	2

CONTROL: 1

0	Estimated unit cost	375
1	Corresponding lot size	100
2	LRA mean time between failures (hours)	27855
3	Mean time to fault isolate, R & R this LRA (hours)	3
4	Mean time to repair LRA (hours)	1
5	LRA duty cycle (decimal)	1
6	LRA specific support and test hardware cost	67
7	Training hours required for repair of LRA	1
8	LRA repair material cost per failure	30
9	Pages of documentation for repair description	21
10	Quantity of similar assemblies	1

PWR ASSY: 1

0	Estimated unit cost	180
1	Corresponding lot size	100
2	LRA mean time between failures (hours)	25974
3	Mean time to fault isolate, R & R this LRA (hours)	3
4	Mean time to repair LRA (hours)	1
5	LRA duty cycle (decimal)	1
6	LRA specific support and test hardware cost	67
7	Training hours required for repair of LRA	1
8	LRA repair material cost per failure	30
9	Pages of documentation for repair description	21
10	Quantity of similar assemblies	1

TUNR/MXR: 1

0	Estimated unit cost	370
1	Corresponding lot size	100
2	LRA mean time between failures (hours)	12937
3	Mean time to fault isolate, R & R this LRA (hours)	3
4	Mean time to repair LRA (hours)	1
5	LRA duty cycle (decimal)	1
6	LRA specific support and test hardware cost	67
7	Training hours required for repair of LRA	1
8	LRA repair material cost per failure	30
9	Pages of documentation for repair description	21
10	Quantity of similar assemblies	1

LRA Configuration for SINCGARS

IF DEMOD: 1

0	Estimated unit cost	325
1	Corresponding lot size	100
2	LRA mean time between failures (hours)	18868
3	Mean time to fault isolate, R & R this LRA (hours)	3
4	Mean time to repair LRA (hours)	1
5	LRA duty cycle (decimal)	1
6	LRA specific support and test hardware cost	67
7	Training hours required for repair of LRA	1
8	LRA repair material cost per failure	30
9	Pages of documentation for repair description	21
10	Quantity of similar assemblies	1

EXCITER: 1

0	Estimated unit cost	950
1	Corresponding lot size	100
2	LRA mean time between failures (hours)	11737
3	Mean time to fault isolate, R & R this LRA (hours)	3
4	Mean time to repair LRA (hours)	1
5	LRA duty cycle (decimal)	1
6	LRA specific support and test hardware cost	67
7	Training hours required for repair of LRA	1
8	LRA repair material cost per failure	30
9	Pages of documentation for repair description	21
10	Quantity of similar assemblies	2

SYNTHSIZER: 1

0	Estimated unit cost	525
1	Corresponding lot size	100
2	LRA mean time between failures (hours)	15674
3	Mean time to fault isolate, R & R this LRA (hours)	3
4	Mean time to repair LRA (hours)	1.5
5	LRA duty cycle (decimal)	1
6	LRA specific support and test hardware cost	67
7	Training hours required for repair of LRA	1
8	LRA repair material cost per failure	30
9	Pages of documentation for repair description	21
10	Quantity of similar assemblies	2

TWO-WIRE: 1

0	Estimated unit cost	160
1	Corresponding lot size	100
2	LRA mean time between failures (hours)	22624
3	Mean time to fault isolate, R & R this LRA (hours)	3
4	Mean time to repair LRA (hours)	1
5	LRA duty cycle (decimal)	1
6	LRA specific support and test hardware cost	67
7	Training hours required for repair of LRA	0
8	LRA repair material cost per failure	200
9	Pages of documentation for repair description	21
10	Quantity of similar assemblies	3

LRA Configuration for SINCGARS

SWITCH: 1
0 Estimated unit cost.. 400
1 Corresponding lot size... 100
2 LRA mean time between failures (hours).............................. 12837
3 Mean time to fault isolate, R & R this LRA (hours).................... 3
4 Mean time to repair LRA (hours)....................................... 1
5 LRA duty cycle (decimal).. 1
6 LRA specific support and test hardware cost.......................... 67
7 Training hours required for repair of LRA............................. 1
8 LRA repair material cost per failure................................. 30
9 Pages of documentation for repair description........................ 21
10 Quantity of similar assemblies....................................... 2

REMOTE I/O: 1
0 Estimated unit cost.. 225
1 Corresponding lot size... 100
2 LRA mean time between failures (hours).............................. 44444
3 Mean time to fault isolate, R & R this LRA (hours).................... 3
4 Mean time to repair LRA (hours)....................................... 1
5 LRA duty cycle (decimal).. 1
6 LRA specific support and test hardware cost.......................... 67
7 Training hours required for repair of LRA............................. 1
8 LRA repair material cost per failure................................. 30
9 Pages of documentation for repair description........................ 21
10 Quantity of similar assemblies....................................... 1

ANT CONTRL: 1
0 Estimated unit cost.. 175
1 Corresponding lot size... 100
2 LRA mean time between failures (hours).............................. 28818
3 Mean time to fault isolate, R & R this LRA (hours).................... 3
4 Mean time to repair LRA (hours)....................................... 1
5 LRA duty cycle (decimal).. 1
6 LRA specific support and test hardware cost.......................... 67
7 Training hours required for repair of LRA............................. 1
8 LRA repair material cost per failure................................. 30
9 Pages of documentation for repair description........................ 21
10 Quantity of similar assemblies....................................... 1

AUD PWR SUP: 1
0 Estimated unit cost.. 210
1 Corresponding lot size... 100
2 LRA mean time between failures (hours).............................. 32573
3 Mean time to fault isolate, R & R this LRA (hours).................... 3
4 Mean time to repair LRA (hours)....................................... 1
5 LRA duty cycle (decimal).. 1
6 LRA specific support and test hardware cost.......................... 67
7 Training hours required for repair of LRA............................. 1
8 LRA repair material cost per failure................................. 30
9 Pages of documentation for repair description........................ 21
10 Quantity of similar assemblies....................................... 1

LRA Configuration for SINCGARS

AUD DATA I/O: 1
0 Estimated unit cost.. 260
1 Corresponding lot size... 100
2 LRA mean time between failures (hours)................................ 14881
3 Mean time to fault isolate, R & R this LRA (hours)..................... 3
4 Mean time to repair LRA (hours)... 1
5 LRA duty cycle (decimal).. 1
6 LRA specific support and test hardware cost............................ 67
7 Training hours required for repair of LRA................................ 1
8 LRA repair material cost per failure..................................... 30
9 Pages of documentation for repair description.......................... 21
10 Quantity of similar assemblies... 1

BATTERY CASE: 1
0 Estimated unit cost.. 50
1 Corresponding lot size... 100
2 LRA mean time between failures (hours)................................ 86957
3 Mean time to fault isolate, R & R this LRA (hours)..................... 3
4 Mean time to repair LRA (hours)... 10
5 LRA duty cycle (decimal).. 1
6 LRA specific support and test hardware cost............................ 67
7 Training hours required for repair of LRA................................ 0
8 LRA repair material cost per failure..................................... 60
9 Pages of documentation for repair description.......................... 21
10 Quantity of similar assemblies... 3

AUD DAT CONTRL: 1
0 Estimated unit cost.. 180
1 Corresponding lot size... 100
2 LRA mean time between failures (hours)................................ 21978
3 Mean time to fault isolate, R & R this LRA (hours)..................... 3
4 Mean time to repair LRA (hours)... 1
5 LRA duty cycle (decimal).. 1
6 LRA specific support and test hardware cost............................ 67
7 Training hours required for repair of LRA................................ 1
8 LRA repair material cost per failure..................................... 30
9 Pages of documentation for repair description.......................... 21
10 Quantity of similar assemblies... 1

ANTENNA: 1
0 Estimated unit cost.. 40
1 Corresponding lot size... 100
2 LRA mean time between failures (hours)................................ 13158
3 Mean time to fault isolate, R & R this LRA (hours)..................... 3
4 Mean time to repair LRA (hours)... 2
5 LRA duty cycle (decimal).. 1
6 LRA specific support and test hardware cost............................ 0
7 Training hours required for repair of LRA................................ 0
8 LRA repair material cost per failure..................................... 0
9 Pages of documentation for repair description.......................... 0
10 Quantity of similar assemblies... 3

LRA Configuration for SINCGARS

HANDSET: 1

0	Estimated unit cost	80
1	Corresponding lot size	100
2	LRA mean time between failures (hours)	780
3	Mean time to fault isolate, R & R this LRA (hours)	3
4	Mean time to repair LRA (hours)	2
5	LRA duty cycle (decimal)	1
6	LRA specific support and test hardware cost	0
7	Training hours required for repair of LRA	0
8	LRA repair material cost per failure	0
9	Pages of documentation for repair description	0
10	Quantity of similar assemblies	3

CHASSIS

INPUT DATA
****

Quantity	1	UC(lot)	1400	lot	100	MTBF	14006
MTRR	3.0	MTTR	1.0	Duty cycle	1.0	S+TE	67
Trng hrs	1	Repair parts $	20	Tech doc pp	21	QSA	2

****************** SUPPORT POLICY SUMMARIES ****************

	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	46846.4	40340.8	40227.0	49635.4
INITIAL COSTS:				
Production	39356.8	39356.8	39356.8	39356.8
Training	0.0	0.1	0.9	0.0
Spares	284.5	280.3	172.5	1830.2
S+TE	0.0	80.1	81.9	0.0
Tech. Doc.	0.0	4.2	4.2	0.0
**TOTAL	39641.3	39721.5	39616.2	41187.0
OPERATION AND SUPPORT COSTS:				
Wage	251.9	344.9	335.8	251.9
Training	0.0	0.1	2.7	0.0
Spares	82.0	82.0	82.0	8196.5
Repair	6871.3	137.4	137.4	0.0
Transportation	0.0	3.1	0.0	0.0
S+TE	0.0	49.2	50.3	0.0
Tech. Doc.	0.0	2.6	2.6	0.0
**TOTAL	7205.1	619.3	610.8	8448.4

Support Posture Assigned: Local Repair
****

CONTROL

INPUT DATA
****

Quantity	1	UC(lot)	375	lot	100	MTBF	27855
MTRR	3.0	MTTR	1.0	Duty cycle	1.0	S+TE	67
Trng hrs	1	Repair parts $	30	Tech doc pp	21	QSA	1

****************** SUPPORT POLICY SUMMARIES ****************

	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	14184.4	11016.6	11001.7	12029.9
INITIAL COSTS:				
Production	10542.0	10542.0	10542.0	10542.0
Training	0.0	0.1	0.9	0.0
Spares	49.7	48.6	33.6	257.4
S+TE	0.0	80.1	81.9	0.0
Tech. Doc.	0.0	4.2	4.2	0.0
**TOTAL	10591.7	10675.0	10662.6	10799.4
OPERATION AND SUPPORT COSTS:				
Wage	126.7	173.4	168.9	126.7
Training	0.0	0.1	2.7	0.0
Spares	11.0	11.0	11.0	1103.9
Repair	3455.0	103.6	103.6	0.0
Transportation	0.0	1.6	0.0	0.0
S+TE	0.0	49.2	50.3	0.0
Tech. Doc.	0.0	2.6	2.6	0.0
**TOTAL	3592.7	341.6	339.1	1230.6

Support Posture Assigned: Military Depot
****

IF DEMOD

INPUT DATA

****

Quantity	1	UC(lot)	325	lot	100	MTBF	18868
MTRR	3.0	MTTR	1.0	Duty cycle	1.0	S+TE	67
Trng hrs	1	Repair parts $	30	Tech doc pp	21	QSA	1

******************* SUPPORT POLICY SUMMARIES ****************

	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	14493.2	9752.3	9725.4	11057.0
INITIAL COSTS:				
Production	9136.4	9136.4	9136.4	9136.4
Training	0.0	0.1	0.9	0.0
Spares	55.0	54.0	30.0	321.1
S+TE	0.0	80.1	81.9	0.0
Tech. Doc.	0.0	4.2	4.2	0.0
**TOTAL	9191.4	9274.8	9253.4	9457.5
OPERATION AND SUPPORT COSTS:				
Wage	187.0	256.0	249.3	187.0
Training	0.0	0.1	2.7	0.0
Spares	14.1	14.1	14.1	1412.4
Repair	5100.6	153.0	153.0	0.0
Transportation	0.0	2.3	0.0	0.0
S+TE	0.0	49.2	50.3	0.0
Tech. Doc.	0.0	2.6	2.6	0.0
**TOTAL	5301.7	477.4	472.0	1599.4

Support Posture Assigned: Military Depot

****

TUNR/MXR

INPUT DATA
****

Quantity	1	UC(lot)	370	lot	100	MTBF	12937
MTRR	3.0	MTTR	1.0	Duty cycle	1.0	S+TE	67
Trng hrs	1	Repair parts $	30	Tech doc pp	21	QSA	1

****************** SUPPORT POLICY SUMMARIES ****************

	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	18213.3	11236.7	11200.1	13538.3
INITIAL COSTS:				
Production	10401.4	10401.4	10401.4	10401.4
Training	0.0	0.1	0.9	0.0
Spares	76.6	75.5	45.9	519.0
S+TE	0.0	80.1	81.9	0.0
Tech. Doc.	0.0	4.2	4.2	0.0
**TOTAL	10478.1	10561.4	10534.3	10920.4
OPERATION AND SUPPORT COSTS:				
Wage	272.7	373.4	363.6	272.7
Training	0.0	0.1	2.7	0.0
Spares	23.5	23.5	23.5	2345.
Repair	7439.0	223.2	223.2	0.0
Transportation	0.0	3.3	0.0	0.0
S+TE	0.0	49.2	50.3	0.0
Tech. Doc.	0.0	2.6	2.6	0.0
**TOTAL	7735.2	675.3	665.8	2617.9

Support Posture Assigned: Military Depot
****

PWR ASSY

INPUT DATA
****

Quantity	1	UC(lot)	180	lot	100	MTBF	25974
MTRR	3.0	MTTR	1.0	Duty cycle	1.0	S+TE	67
Trng hrs	1	Repair parts $	30	Tech doc pp	21	QSA	1

****************** SUPPORT POLICY SUMMARIES ****************

	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	8930.8	5524.9	5516.8	5895.6
INITIAL COSTS:				
Production	5060.2	5060.2	5060.2	5060.2
Training	0.0	0.1	0.9	0.0
Spares	23.9	23.9	16.2	131.4
S+TE	0.0	80.1	81.9	0.0
Tech. Doc.	0.0	4.2	4.2	0.0
**TOTAL	5084.1	5168.5	5163.3	5191.6
OPERATION AND SUPPORT COSTS:				
Wage	135.8	186.0	181.1	135.8
Training	0.0	0.1	2.7	0.0
Spares	5.7	5.7	5.7	568.3
Repair	3705.2	111.2	111.2	0.0
Transportation	0.0	1.7	0.0	0.0
S+TE	0.0	49.2	50.3	0.0
Tech. Doc.	0.0	2.6	2.6	0.0
**TOTAL	3846.7	356.4	353.5	704.1

Support Posture Assigned: Military Depot
****

EXCITER

INPUT DATA
****

Quantity	1	UC(lot)	950	lot	100	MTBF	11737
MTRR	3.0	MTTR	1.0	Duty cycle	1.0	S+TE	67
Trng hrs	1	Repair parts $	30	Tech doc pp	21	QSA	2

******************* SUPPORT POLICY SUMMARIES ****************

	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	35476.6	27774.0	27681.1	35102.8
INITIAL COSTS:				
Production	26706.4	26706.4	26706.4	26706.4
Training	0.0	0.1	0.9	0.0
Spares	203.6	203.6	119.1	1458.7
S+TE	0.0	80.1	81.9	0.0
Tech. Doc.	0.0	4.2	4.2	0.0
**TOTAL	26910.0	26994.4	26912.4	28165.1
OPERATION AND SUPPORT COSTS:				
Wage	300.6	411.6	400.8	300.6
Training	0.0	0.1	2.7	0.0
Spares	66.4	66.4	66.4	6637.1
Repair	8199.6	246.0	246.0	0.0
Transportation	0.0	3.7	0.0	0.0
S+TE	0.0	49.2	50.3	0.0
Tech. Doc.	0.0	2.6	2.6	0.0
**TOTAL	8566.6	779.6	768.7	6937.7

Support Posture Assigned: Local Repair
****

SYNTHSIZER

INPUT DATA
****

Quantity	1	UC(lot)	525	lot	100	MTBF	15674
MTRR	3.0	MTTR	1.5	Duty cycle	1.0	S+TE	67
Trng hrs	1	Repair parts $	30	Tech doc pp	21	QSA	2

******************** SUPPORT POLICY SUMMARIES ****************

	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	21245.9	15552.3	15500.0	18342.8
INITIAL COSTS:				
Production	14758.8	14758.8	14758.8	14758.8
Training	0.0	0.1	0.9	0.0
Spares	94.5	92.9	49.3	612.3
S+TE	0.0	80.1	81.9	0.0
Tech. Doc.	0.0	4.2	4.2	0.0
**TOTAL	14853.3	14936.1	14895.1	15371.1
OPERATION AND SUPPORT COSTS:				
Wage	225.1	349.8	337.6	225.1
Training	0.0	0.1	2.7	0.0
Spares	27.5	27.5	27.5	2746.6
Repair	6140.0	184.2	184.2	0.0
Transportation	0.0	2.8	0.0	0.0
S+TE	0.0	49.2	50.3	0.0
Tech. Doc.	0.0	2.6	2.6	0.0
**TOTAL	6392.6	616.1	604.9	2971.7

Support Posture Assigned: Local Repair
****

TWO-WIRE

INPUT DATA
****

Quantity	1	UC(lot)	160	lot	100	MTBF	22624
MTRR	3.0	MTTR	1.0	Duty cycle	1.0	S+TE	67
Trng hrs	0	Repair parts $	200	Tech doc pp	21	QSA	3

******************* SUPPORT POLICY SUMMARIES ****************

	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	8936.4	5728.9	5715.9	5366.3
INITIAL COSTS:				
Production	4497.9	4497.9	4497.9	4497.9
Training	0.0	0.0	0.0	0.0
Spares	22.9	22.9	14.5	132.5
S+TE	0.0	80.1	81.9	0.0
Tech. Doc.	0.0	4.2	4.2	0.0
**TOTAL	4520.8	4605.1	4598.5	4630.4
OPERATION AND SUPPORT COSTS:				
Wage	155.9	213.5	207.9	155.9
Training	0.0	0.0	0.0	0.0
Spares	5.8	5.8	5.8	579.9
Repair	4253.8	850.8	850.8	0.0
Transportation	0.0	1.9	0.0	0.0
S+TE	0.0	49.2	50.3	0.0
Tech. Doc.	0.0	2.6	2.6	0.0
**TOTAL	4415.6	1123.8	1117.4	735.9

Support Posture Assigned: Discard
****

SWITCH

INPUT DATA
****

Quantity	1	UC(lot)	400	lot	100	MTBF	12837
MTRR	3.0	MTTR	1.0	Duty cycle	1.0	S+TE	67
Trng hrs	1	Repair parts $	30	Tech doc pp	21	QSA	2

****************** SUPPORT POLICY SUMMARIES ****************

	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	19125.0	12093.0	12053.9	14639.6
INITIAL COSTS:				
Production	11244.8	11244.8	11244.8	11244.8
Training	0.0	0.1	0.9	0.0
Spares	82.9	81.7	49.7	564.8
S+TE	0.0	80.1	81.9	0.0
Tech. Doc.	0.0	4.2	4.2	0.0
**TOTAL	11327.7	11410.9	11381.4	11809.6
OPERATION AND SUPPORT COSTS:				
Wage	274.8	376.3	366.4	274.8
Training	0.0	0.1	2.7	0.0
Spares	25.6	25.6	25.6	2555.1
Repair	7497.0	224.9	224.9	0.0
Transportation	0.0	3.4	0.0	0.0
S+TE	0.0	49.2	50.3	0.0
Tech. Doc.	0.0	2.6	2.6	0.0
**TOTAL	7797.4	682.1	672.5	2829.9

Support Posture Assigned: Local Repair
****

REMOTE I/O

INPUT DATA
****

Quantity	1	UC(lot)	225	lot	100	MTBF	44444
MTRR	3.0	MTTR	1.0	Duty cycle	1.0	S+TE	67
Trng hrs	1	Repair parts $	30	Tech doc pp	21	QSA	1

****************** SUPPORT POLICY SUMMARIES ****************

	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	8596.5	6662.0	6656.1	6919.9
INITIAL COSTS:				
Production	6325.2	6325.2	6325.2	6325.2
Training	0.0	0.1	0.9	0.0
Spares	22.4	21.7	13.4	100.2
S+TE	0.0	80.1	81.9	0.0
Tech. Doc.	0.0	4.2	4.2	0.0
**TOTAL	6347.6	6431.3	6425.5	6425.4
OPERATION AND SUPPORT COSTS:				
Wage	79.4	108.7	105.8	79.4
Training	0.0	0.1	2.7	0.0
Spares	4.2	4.2	4.2	415.1
Repair	2165.4	65.0	65.0	0.0
Transportation	0.0	1.0	0.0	0.0
S+TE	0.0	49.2	50.3	0.0
Tech. Doc.	0.0	2.6	2.6	0.0
**TOTAL	2248.9	230.7	230.5	494.5

Support Posture Assigned: Military Depot
****

ANT CONTRL

INPUT DATA
****

Quantity	1	UC(lot)	175	lot	100	MTBF	28818
MTRR	3.0	MTTR	1.0	Duty cycle	1.0	S+TE	67
Trng hrs	1	Repair parts $	30	Tech doc pp	21	QSA	1

****************** SUPPORT POLICY SUMMARIES ****************

	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	8409.7	5352.9	5346.2	5656.8
INITIAL COSTS:				
Production	4919.6	4919.6	4919.6	4919.6
Training	0.0	0.1	0.9	0.0
Spares	23.2	22.7	15.7	116.8
S+TE	0.0	80.1	81.9	0.0
Tech. Doc.	0.0	4.2	4.2	0.0
**TOTAL	4942.8	5026.6	5022.2	5036.4
OPERATION AND SUPPORT COSTS:				
Wage	122.4	167.6	163.2	122.4
Training	0.0	0.1	2.7	0.0
Spares	5.0	5.0	5.0	498.0
Repair	3339.5	100.2	100.2	0.0
Transportation	0.0	1.5	0.0	0.0
S+TE	0.0	49.2	50.3	0.0
Tech. Doc.	0.0	2.6	2.6	0.0
**TOTAL	3466.9	326.2	324.0	620.4

Support Posture Assigned: Military Depot
****

AUD PWR SUP

INPUT DATA
****

Quantity	1	UC(lot)	210	lot	100	MTBF	32573
MTRR	3.0	MTTR	1.0	Duty cycle	1.0	S+TE	67
Trng hrs	1	Repair parts $	30	Tech doc pp	21	QSA	1

	****************** SUPPORT POLICY SUMMARIES ****************			
	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	8998.7	6309.8	6297.2	6666.9
INITIAL COSTS:				
Production	5903.5	5903.5	5903.5	5903.5
Training	0.0	0.1	0.9	0.0
Spares	27.0	26.4	12.8	126.4
S+TE	0.0	80.1	81.9	0.0
Tech. Doc.	0.0	4.2	4.2	0.0
**TOTAL	5930.6	6014.3	6003.2	6029.9
OPERATION AND SUPPORT COSTS:				
Wage	108.3	148.3	144.4	108.3
Training	0.0	0.1	2.7	0.0
Spares	5.3	5.3	5.3	528.7
Repair	2954.6	88.6	88.6	0.0
Transportation	0.0	1.3	0.0	0.0
S+TE	0.0	49.2	50.3	0.0
Tech. Doc.	0.0	2.6	2.6	0.0
**TOTAL	3068.1	295.5	293.9	637.0

Support Posture Assigned: Military Depot
****

AUD DATA I/O

INPUT DATA
****

Quantity	1	UC(lot)	260	lot	100	MTBF	14881
MTRR	3.0	MTTR	1.0	Duty cycle	1.0	S+TE	67
Trng hrs	1	Repair parts $	30	Tech doc pp	21	QSA	1

******************* SUPPORT POLICY SUMMARIES ****************

	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	14080.4	8033.2	8000.7	9301.7
INITIAL COSTS:				
Production	7309.1	7309.1	7309.1	7309.1
Training	0.0	0.1	0.9	0.0
Spares	52.7	51.9	24.6	322.8
S+TE	0.0	80.1	81.9	0.0
Tech. Doc.	0.0	4.2	4.2	0.0
**TOTAL	7361.8	7445.4	7420.6	7631.9
OPERATION AND SUPPORT COSTS:				
Wage	237.1	324.6	316.1	237.1
Training	0.0	0.1	2.7	0.0
Spares	14.3	14.3	14.3	1432.7
Repair	6467.2	194.0	194.0	0.0
Transportation	0.0	2.9	0.0	0.0
S+TE	0.0	49.2	50.3	0.0
Tech. Doc.	0.0	2.6	2.6	0.0
**TOTAL	6718.6	587.8	580.0	1669.8

Support Posture Assigned: Military Depot
****

BATTERY CASE

INPUT DATA
****

Quantity	1	UC(lot)	50	lot	100	MTBF	86957
MTRR	3.0	MTTR	10.0	Duty cycle	1.0	S+TE	67
Trng hrs	0	Repair parts $	60	Tech doc pp	21	QSA	3

******************* SUPPORT POLICY SUMMARIES ****************

	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	2556.6	1802.7	1790.1	1505.4
INITIAL COSTS:				
Production	1405.6	1405.6	1405.6	1405.6
Training	0.0	0.0	0.0	0.0
Spares	3.2	3.2	2.9	12.1
S+TE	0.0	80.1	81.9	0.0
Tech. Doc.	0.0	4.2	4.2	0.0
**TOTAL	1408.8	1493.1	1494.6	1417.7
OPERATION AND SUPPORT COSTS:				
Wage	40.6	190.4	175.8	40.6
Training	0.0	0.0	0.0	0.0
Spares	0.5	0.5	0.5	47.1
Repair	1106.7	66.4	66.4	0.0
Transportation	0.0	0.5	0.0	0.0
S+TE	0.0	49.2	50.3	0.0
Tech. Doc.	0.0	2.6	2.6	0.0
**TOTAL	1147.8	309.6	295.6	87.7

Support Posture Assigned: Discard
****

AUD DAT CONTRL

INPUT DATA
****

Quantity	1	UC(lot)	180	lot	100	MTBF	21978
MTRR	3.0	MTTR	1.0	Duty cycle	1.0	S+TE	67
Trng hrs	1	Repair parts $	30	Tech doc pp	21	QSA	1

	******************* SUPPORT POLICY SUMMARIES ****************			
	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	9635.4	5585.5	5571.2	6048.4
INITIAL COSTS:				
Production	5060.2	5060.2	5060.2	5060.2
Training	0.0	0.1	0.9	0.0
Spares	29.2	29.2	16.4	156.2
S+TE	0.0	80.1	81.9	0.0
Tech. Doc.	0.0	4.2	4.2	0.0
**TOTAL	5089.3	5173.7	5163.5	5216.3
OPERATION AND SUPPORT COSTS:				
Wage	160.5	219.8	214.0	160.5
Training	0.0	0.1	2.7	0.0
Spares	6.7	6.7	6.7	671.6
Repair	4378.9	131.4	131.4	0.0
Transportation	0.0	2.0	0.0	0.0
S+TE	0.0	49.2	50.3	0.0
Tech. Doc.	0.0	2.6	2.6	0.0
**TOTAL	4546.1	411.8	407.7	832.1

Support Posture Assigned: Military Depot
****

ANTENNA

INPUT DATA
****

Quantity	1	UC(lot)	40	lot	100	MTBF	13158
MTRR	3.0	MTTR	2.0	Duty cycle	1.0	S+TE	0
Trng hrs	0	Repair parts $	0	Tech doc pp	0	QSA	3

****************** SUPPORT POLICY SUMMARIES ****************

	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	8717.5	1733.7	1707.9	1697.2
INITIAL COSTS:				
Production	1124.5	1124.5	1124.5	1124.5
Training	0.0	0.0	0.0	0.0
Spares	8.3	8.2	5.0	55.3
S+TE	0.0	80.0	80.0	0.0
Tech. Doc.	0.0	0.0	0.0	0.0
**TOTAL	1132.8	1212.6	1209.4	1179.8
OPERATION AND SUPPORT COSTS:				
Wage	268.1	466.1	446.9	268.1
Training	0.0	0.0	0.0	0.0
Spares	2.5	2.5	2.5	249.3
Repair	7314.1	0.0	0.0	0.0
Transportation	0.0	3.3	0.0	0.0
S+TE	0.0	49.2	49.2	0.0
Tech. Doc.	0.0	0.0	0.0	0.0
**TOTAL	7584.7	521.1	498.5	517.4

Support Posture Assigned: Discard
****

HANDSET

INPUT DATA
****

Quantity	1	UC(lot)	80	lot	100	MTBF	780
MTRR	3.0	MTTR	2.0	Duty cycle	1.0	S+TE	0
Trng hrs	0	Repair parts $	0	Tech doc pp	0	QSA	3

******************* SUPPORT POLICY SUMMARIES ****************

	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	130370.0	10511.9	10063.6	16903.1
INITIAL COSTS:				
Production	2249.0	2249.0	2249.0	2249.0
Training	0.0	0.0	0.0	0.0
Spares	130.6	130.6	63.1	1721.0
S+TE	0.0	80.0	80.0	0.0
Tech. Doc.	0.0	0.0	0.0	0.0
**TOTAL	2379.6	2459.6	2392.1	3969.9
OPERATION AND SUPPORT COSTS:				
Wage	4522.9	7863.5	7538.2	4522.9
Training	0.0	0.0	0.0	0.0
Spares	84.1	84.1	84.1	8410.3
Repair	123383.0	0.0	0.0	0.0
Transportation	0.0	55.5	0.0	0.0
S+TE	0.0	49.2	49.2	0.0
Tech. Doc.	0.0	0.0	0.0	0.0
**TOTAL	127990.0	8052.3	7671.5	12933.2

Support Posture Assigned: Discard
****

BATTERY

INPUT DATA
****

Quantity	1	UC(lot)	80	lot	100	MTBF	24
MTRR	0.3	MTTR	2.0	Duty cycle	1.0	S+TE	0
Trng hrs	0	Repair parts $	0	Tech doc pp	0	QSA	3

	******************* SUPPORT POLICY SUMMARIES *****************			
	Contractor Depot	Military Depot	Local Repair	Discard
LIFE CYCLE COST	%4030330.0	130887.0	116801.0	342672.0
INITIAL COSTS:				
Production	2249.0	2249.0	2249.0	2249.0
Training	0.0	0.0	0.0	0.0
Spares	3153.5	3153.5	1442.7	54839.4
S+TE	0.0	80.0	80.0	0.0
Tech. Doc.	0.0	0.0	0.0	0.0
**TOTAL	5402.5	5482.5	3771.7	57088.4
OPERATION AND SUPPORT COSTS:				
Wage	12249.6	120818.0	110247.0	12249.6
Training	0.0	0.0	0.0	0.0
Spares	2733.3	2733.3	2733.3	273334.0
Repair	%4009950.0	0.0	0.0	0.0
Transportation	0.0	1804.5	0.0	0.0
S+TE	0.0	49.2	49.2	0.0
Tech. Doc.	0.0	0.0	0.0	0.0
**TOTAL	%4024930.0	125405.0	113029.0	285584.0

Support Posture Assigned: Discard
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